

SCIENCE SIMPLIFIED

CHEMISTRY.

BY
PROFESSOR PEPPER
(LATE OF THE POLYTECHNIC)

74 ILLUSTRATIONS



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CHEMISTRY.

EMBRACING

THE METALS AND ELEMENTS WHICH ARE NOT METALLIC.

BY
^{John Henry}
J. H. PEPPER,

*Late Professor of Chemistry, and Honorary Director of the Royal Polytechnic Institution;
Author of various Works for Youth, &c.*

WITH NUMEROUS ILLUSTRATIONS.



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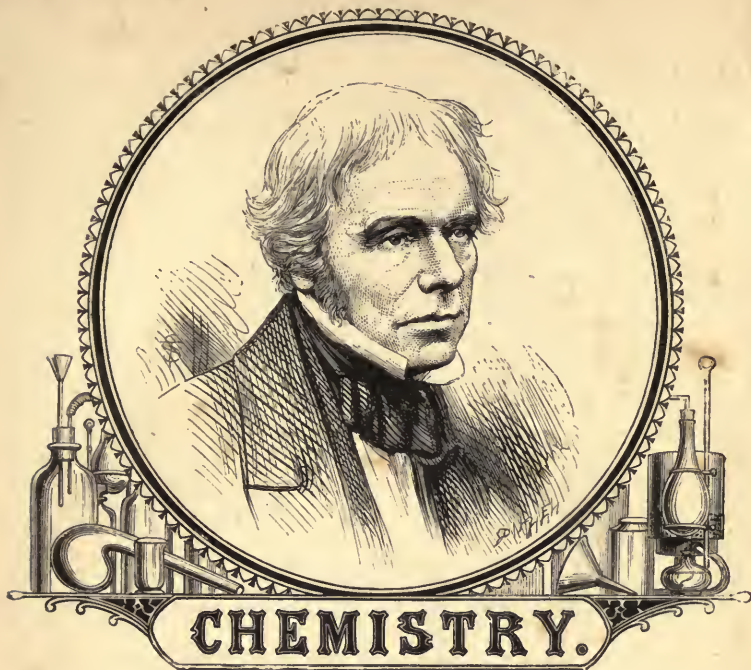
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Yours Truly affectionately
M. Faraday

Portrait and Signature of Faraday.

The former from a photograph by Mr. James How, successor to Knight and Co., of Foster Lane, Cheapside.

CHEMISTRY.

THE son of a smith—the apprentice of a bookseller and bookbinder in Blandford Street, Manchester Square—a journeyman at some other place of business—and subsequently engaged by Sir Humphrey Davy at weekly wages—no lordly patronage heralded the approach of FARADAY: he was indebted to no one except another scientific man, like himself an humble beginner—a chemist's apprentice, a washer of bottles. And yet he lived to make a name that few have or will ever be able to achieve. What does he say of himself?

"I was formerly a bookseller and binder, but am now turned '*philosopher*,' which happened thus: whilst an apprentice, I for amusement learned a little chemistry and other parts of philosophy, and felt an earnest desire to proceed in that way further. After being a journeyman for six months under a disagreeable master, I gave up my business, and through the interest of one Sir H. Davy filled the situation of chemical assistant to the Royal Institution of Great Britain, in which office I now remain, and where I am constantly employed in observing the works of Nature, and tracing the manner in which she directs the order and arrangement of the world."*

On the 18th March, 1813, it was resolved "That Michael Faraday be engaged to fill the situation lately occupied by Mr. Payne, on the same terms."

Faraday accompanied Sir H. Davy to Rome, and was re-engaged by the Royal Institution managers on the 15th May, 1815; and as his first private and original sacrifices of time, energy, and talent were made to "Chemistry," his portrait is placed at the head of this section.

What income Faraday derived from the Royal Institution is not exactly known. The writer has heard the late Mr. Robert Murray say that he had only £200 per annum, and apartments, for a very long period; until somebody suggested that he was no longer an assistant, but a "master," and ought to be paid as a "philosopher." Much or little, it affected not Faraday: his private charities and good deeds are known only to the Great Giver of all things.

The "Mechanic's Magazine," speaking in the hearty truthfulness of independent journalism, said, in October, 1859, that which carried conviction to the hearts of many who see how often science is degraded into "flunkeyism," instead of being elevated to "Faradism,"—

"The other characteristic of our time to which we refer is its boldness, comprehensiveness, and certainty of mental inquiry, which expresses itself in its favourite term—science. We had a notable example of this in the speech of the Prince Consort at Aberdeen, which we reprinted in our journal a fortnight ago. It was a fine specimen of the best mind among us. What choice, pure English the language was, and of such delicate precision and beauty! What graceful personal modesty the speaker showed! How full the discourse was of the old German solidity and seriousness of purpose, that marks all the German people, whether in the old Fatherland or in Angleland. The term 'science' in this address is made to embrace the whole range of the human mind. There are three objects of man's contemplation and inquiry—Nature, Man, God. The human mind has two methods of working—analysis and synthesis. It dissects into parts, observes, examines, reasons about each part; or intuitively it grasps the law that binds and controls the parts and knits them into a whole. All follow this method, says the Prince—the child, the man of mere practical instinct, or the philosopher. The child, as soon as his first surprise and ecstasy at the new universe subside a little, begins to ask the *how* and *why* of things. He practises his analysis by pulling his toy to pieces to discover how it works; or he performs a splendid generalization; as, for example, when the fire burns him, he affirms to himself that fire burns in every instance, at all places and times, though he has only experienced one instance of its burning power. The practical man is instinctively impelled to philosophize, in his rough, homespun method, on the facts he is brought into contact

* Tyndall "On Faraday as a Discoverer."

with. But the philosopher, by stronger instinct and by conscious self-determination, directs his eye to every part of the great All.

"Science, the Prince hints, has been of slow growth in England, partly because we English are so wedded to what is immediately useful, what immediately shows a return in pounds, shillings, and pence; and partly from our excessive devotion to antiquity, that 'till of late has almost systematically excluded from our school and university education' the great subjects and the results of modern inquiry, while it has given to antique things that liveliness of interest we feel all through life in the subjects we studied in early years.

"The illustrious speaker lays great stress on the *absence* of all *professionalism* and *officialism* from science. *Knowledge, in his eyes, has no aristocracy or priesthood.* Its genuine students are not '*a secret confraternity of men jealously guarding the mysteries of their profession;*' their activity is 'the republican activity of the Roman Forum.' But if boldness and freedom, the Prince reminds us, are the characteristics of the philosopher, equally so is reverence. The more he explores the more he becomes aware of '*the boundlessness of the universe, whose confines appear ever to retreat before our finite minds.*' True thinkers are '*not conceited pedants, wrapped up in their own mysterious importance, but humble inquirers after truth; not God-defying Titans, but reverent, pious pilgrims towards a Holy Land—God's truth—God's laws, as manifested in His works, in His creation.*'"

The imponderable forces have already been dealt with, and yet there remain those of Gravitation, Cohesion, Adhesion, and Chemical Action. To speak of the first would be to enter upon the science of astronomy, which is impossible in this work; it is sufficient to refer the reader to the first lines of the epitaph under the statue of Sir Isaac Newton:

HERE LIES INTERRED
ISAAC NEWTON, KNIGHT,
WHO,
WITH AN ENERGY OF MIND ALMOST DIVINE,
GUIDED BY THE LIGHT OF MATHEMATICS PURELY HIS OWN,
FIRST DEMONSTRATED
THE MOTIONS AND FIGURES OF THE PLANETS,
THE PATHS OF THE COMETS,
AND THE CAUSES OF THE TIDES.

The reader working out only the philosophy of the last lines will soon acquire a knowledge of the power supposed to exist, and which by universal consent is called Gravitation.

Newton was born on the 25th December, 1642, and died on the 20th March, 1726. Gravity is defined as that force which tends to make bodies move downwards towards the centre of the earth, and which prevents their being moved upwards. If the atmosphere surrounding our earth were not fixed to it by the invisible chain of gravitation, it would have expanded long ago into space, and no human beings with their present organization would have been left to tell the tale of desertion, for all would have perished for want of air.

The amount of downward force which causes a body to gravitate to the earth is called its "weight."

For the sake of comparison it was found necessary to fix some "standard" to which the weights of different substances might be referred.

Water was selected, because it is to be found in all places and in all seasons: its presence is, in fact, universal; and therefore a pound avoirdupois of water, containing 7,000 grains, of which each 272458 grains are equal to

one cubic inch, is taken as the fixed and determined standard,—provided always that it be estimated at a temperature of 62° F., the barometer being at 30 inches.

As water is taken as the standard for the determination of the specific gravity of solids and liquids, so air at 62° F. and 30 in. barometer is taken for that of all gaseous bodies.

The mode of determining the specific gravity of solids is very simple:

1. Weigh the solid substance in air;
2. Also in water, taking care to prevent air-bubbles adhering to the substance; and this the writer finds is entirely prevented (where the substance is insoluble in alcohol) by dipping the solid into alcohol, and then into several waters, at last placing it in the vessel of water in which the specific gravity is to be ascertained.

3. Divide the gross weight by the loss of weight of water, and the quotient gives the specific gravity.

The specific gravity of liquids is ascertained *directly* by first adjusting a glass bottle (the weight of which is balanced by a counterpoise) to hold 1,000 grains: if the same bottle be filled with alcohol, it weighs less than water, viz., 792 grains; if filled with oil of vitriol, it weighs more than the same bulk of water, viz., 1,845 grains. The exact weight is the reading, and no calculation is required.

The determination of the specific gravity of a gas is founded on the same principles, but the most elaborate precautions must be taken. A given volume of air, such as that contained in a wine-flask, is first weighed; then it is emptied by the air-pump and weighed again; lastly, it is weighed full of the gas of which it is required to ascertain the specific gravity. A simple rule-of-three sum determines the question—that is, roughly: to perform the experiment accurately, the precautions insisted on by Regnault (“*Annals de Chemie*,” III., xiv. 211) must be taken.

Daniell defines cohesion to be homogeneous attraction: *ἐμὸς* like, and *γένος*, kind—alike in nature of properties. Two surfaces of lead cohere, provided that they are perfectly clean and bright; two bars of iron sufficiently heated may be welded together by hammering or any other kind of mechanical pressure or force. If metallic contact between the two bars be not well secured by proper handicraft, the weld is imperfect, and the two surfaces of iron do not cohere, but separate on the application of slight mechanical force. A drop of dew on a cabbage-leaf is an excellent illustration of cohesive power in a liquid; and this property has been turned to a good account by Professor Tomlinson, and subsequently by Dr. Moffat, of Glasgow, who has quite dignified an otherwise humble department of physical truth by his efforts to make the new art of Oleography popular.

These oleographs (Fig. 1) indicate special figures always assumed by any particles of oil or other fluids of a kindred nature; therefore they become guides to direct the analyst, who, by consulting these figures, can ascertain whether the oil, tallow, lard, or other kind of grease is really what it purports to be.

Professor Tomlinson was the first to call attention to this peculiar class of experiments, and his original discoveries have been greatly extended by Dr. R. Carter, Moffat Lecturer on Chemistry, Glasgow, to whom the writer is indebted for the originals from which the cuts (Fig. 1) are taken. The latter gentleman's paper in the “*Chemical News*” (Vol. XVIII., No. 473) is so very concise and explanatory of the whole process, that it is given here

nearly *in extenso*. The process will remind the reader of the art of marbling paper, which, like the oleographic process, is one of the most ingenious and amusing that can be introduced to a general audience.

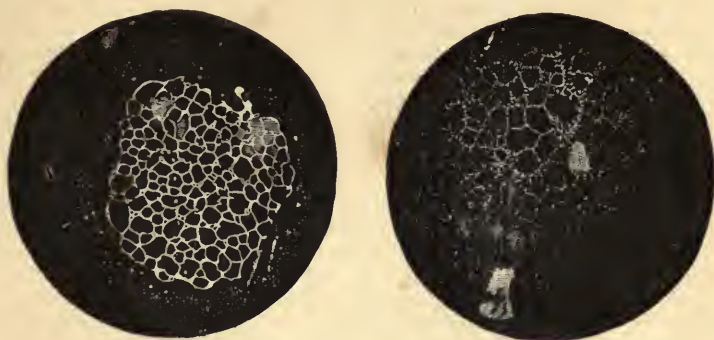


FIG. 1.—*Oleographs of Tallow and Lard, taken by Dr. Moffat*

OLEOGRAPHY: BEING A PROCESS FOR THE UTILIZATION OF
TOMLINSON'S COHESION FIGURES.

"Chemists are aware that most kinds of oil when poured on water spread over its surface, and sooner or later break into variegated patterns, some of which are of great beauty. When we make a few experiments in this direction, attention is attracted to the regularity of the forms assumed, and further, that almost all the common oils give different models of patchwork according to the length of time that the oils are exposed. Experiments conducted in my laboratory show that from the construction of the oil-film we can with considerable certainty determine the kind of oil examined, and also its genuineness. A drop of pure sperm oil let fall on a basin or plate full of water quickly becomes an enlarged circular film of several inches diameter, breaking up near the edges into small round holes. This takes place in about sixty seconds in the case of pure sperm. The centre of the patch is at the same time filled with little holes, somewhat smaller than those at the edges. At two minutes all the little openings are considerably expanded, and they continue to extend until after a lapse of thirty minutes or so, when the oil is broken up and detached. There is value attached to this simple test. Green rape oil breaks up slowly, more so than sperm; but after sixty seconds its pattern is different, the circles being large and beautifully defined. Purified rape oil becomes much larger in the pattern circles than green rape in the same time. Lucca olive gives in one minute a large representation, in two minutes an extraordinary development, and in three minutes a very large likeness.

"Green olive, on the other hand, gives but a small pattern in one minute, and conducts itself quite at variance with Lucca olive. Again, seal and castor oil give forms which are very small compared with many oils. In making these observations it is necessary to attend to the size of the drop of oil, the height it falls, the force with which it does so, the perfect purity of the

cold water, and the stillness of the water at the time. To make the experiment, proceed as follows: From a small dry burette drawn out to a fine point, filled up to a certain mark with the oil, cautiously let fall a single drop at four inches height upon the centre of the water contained in a common soup-plate or glass basin. We shall assume that Lucca olive is taken. The drop should at once spread about four inches on the water circularly. If it does not do so at once, then the plate or the water is not clean, and the water is to be poured out, the plate well washed with water, and again filled. All rubbing with towels is to be avoided. At thirty seconds the appearance of the representation is very lovely, having all the similitude of crochet-work. To give definitions of its many figures, I would need to have Roget's 'Thesaurus of English Words and Phrases' before me. It is needless at present to enumerate the diversity of these oil-films at different periods of time. Tomlinson has enriched science by his masterly descriptions of them. He has done more in this department than any man. To him is due many discoveries in experimental philosophy—facts of the greatest value and importance. It is to him that I would ascribe my recent discovery of the utilization of the cohesion figures of oil on water. Had it not been for a knowledge of the facts connected with his researches in this beautiful and interesting department of science, then in all probability the oil figures would have remained what they are—beautiful to look at, but transient in the extreme. The eye becomes tutored and experienced to these forms, so that it can readily determine the kind of oil under examination. I do not aver this to be the fact in all cases. In very many instances it is so. Indeed, in all that have come under my notice this is the conclusion arrived at. Perfect concordance of results is, I am almost certain, to be obtained when the size of the drop of oil and all other points are rigidly attended to. A slight tremor or shaking of the water is detrimental to a perfect pattern. I have noticed that even a person coughing near the oil-film deranges its conformation.

"Those who have watched these exquisite shapes have often wished to secure them on paper as a kind of photograph,—to have them brought before the eye palpable and fixed, to be seen at once a reality, a permanent image. Many have tried to do so. For long I had attempted to do the same. In many things apparently difficult, yet really simple, we see only that which appears to be insurmountable. It is in their very simplicity, however, that we fail to grasp the solution of the problem. The oil patterns uninjured can as readily be transferred from the surface of water, and permanently fixed to be placed in our albums, as we can pour water from one vessel to another. No matter what colours we desire, we can obtain them of any hue we please. They rival the most beautiful photographs. The faintest tracery is brought out with the most perfect fidelity. Two well-known photographers of this city, to whom I showed them this week, declared they were excellent photographs; and yet not a trace of the chemicals photographers use was employed. The process can be described in three lines: Obtain the oil pattern, note the time, lay a piece of glazed-surface paper on the pattern for an instant, take it off, place on the surface of a plate of ink for a moment, remove and wash off the excess of ink with water, and your pattern is there as it was on the water. You now have an exquisite representation in black, as fine as any photograph. A scarlet is obtained by employing a solution of cochineal or any of the scarlet coal-tar colours. We have them in orange, red, scarlet, black, blue, and other tints. A good result is got by first passing the paper containing the pattern of oil

through ink, and then through cochineal. The principle of the matter is this: the paper absorbs the oil at the several parts, to the exclusion of the water. The ink colours the water parts, but at the same time tints the oil parts very faintly, which gives it the appearance of relief. Any kind of paper almost will do. Tissue, green, glazed, white, &c., give pretty good results. The paper I employ, which I find to take up the most delicate parts, is what is known as white-surface paper (glazed on one side only). We get it cut in circular pieces of about four inches in diameter. A larger pattern could readily be obtained by using a larger drop of oil and a larger size of paper.

"We have been able to take perfect facsimiles of fern-leaves by coating them with oil, placing them on the glazed paper, pressing them against the paper, obtaining a perfect likeness of the fern, and showing it in relief by drawing the paper through ink, or cochineal, or other colour. In printing with oiled types on the paper and colouring afterwards, we have also been able to get beautiful results. I think that paper-stainers and paperhanging manufacturers might be greatly benefited by paying attention to our method.

"I confidently hope to be able to transfer the patterns even to cloth, to stone, &c.

"Scientific chemists are, of course, only interested in this process so far as a test for the purity of oils. I have made many hundreds of experiments with the process, and in a large number of instances have got results with mixtures of oils differing very materially from those with genuine oils. Many more experiments are needed to confirm this, and in a work on the detection of oils, on which I am at present engaged, having added a large number of reliable tests, this will be very fully gone into."

Since the above was written, Mr. Woodward, Lecturer on Chemistry, Midland Institution, Birmingham, has described in the same valuable scientific journal the following method of

EXHIBITING COHESION FIGURES TO A LECTURE AUDIENCE.

"Wishing to exhibit the singular figures discovered by Professor Tomlinson and known as cohesion figures, I proposed adopting the method mentioned by Mr. Reynolds in the 'Chemical News' of November 27th; but it occurred to me that an arrangement similar to that used to show waves in water would probably serve the purpose. I therefore tried the following plan, which, though not so successful as the one I shall afterwards describe, is well worth trying:

"A box with a glass bottom was filled with water, and the lime-light placed underneath the box. On throwing a spot of liquid, giving a cohesion figure, on to the water, the figure, more or less definite, was exhibited on a tracing-paper screen placed above the box. Even with a candle underneath the box the figures were visible, but of course not so sharp as when the oxy-hydrogen light was used. This experiment led me to devise the following arrangement, which, with such liquids as I have tried, serves admirably, the figures being projected on to the screen with great clearness:

"In the first place, several troughs are made to hold the water on which to place the creosote, &c. Those I have are made of plate glass. A piece of glass 5 in. square and $\frac{1}{8}$ in. thick, has a hole 3 in. diameter cut in it, and this, when laid on a plain piece of glass, forms a circular trough, 3 in. diameter and $\frac{1}{8}$ in. deep. An ordinary oxy-hydrogen lantern, from which the nozzle has been removed, is now tilted back so that the light from the lantern is thrown perpen-

dicularly upward, and the trough placed just over the front of the lantern as though it were a lantern-slide. The nozzle of the lantern, fitted to a projecting arm, is then brought over the trough, and an image of the upper surface of the water obtained on the ceiling. On now placing a drop of creosote on the water, an image of it is seen on the ceiling. If it be desired to throw the image on to a vertical screen, a reflecting prism is placed on the nozzle, by which the desired effect is obtained.

"The arrangement will be completely understood by referring to the accompanying figure, in which A is the lantern turned back; C, the chimney; B, the glass trough to hold the water on which the creosote or other liquid is placed; D, nozzle of lantern, supported by the horizontal arm E; F, the reflecting prism; S, screen on which the image is received.

"It should be mentioned that it is necessary to remove the usual taper pipe of the nozzle of the lantern, and substitute a shorter one, so that the figures may be properly focussed, and yet room enough left to introduce a pipette between the nozzle and the trough containing the water."

Adhesion (*ad* to, and *haere* to stick), the tendency which dissimilar bodies have to adhere or stick together, is expressed by Daniell in Johnsonian grandeur as "heterogeneous adhesion." Water dropped into a polished silver spoon wets it: the fluid adheres to the solid.

Absolutely clean platinum may be quicksilverized (is it right to say wetted?) with mercury: the fluid metal adheres to the solid metal; and this property is taken advantage of in the perfection of barometers, in order to prevent the air adhering to the interior of the barometer, creeping up the sides of the tube, and displacing the mercury.

Negretti and Zambra skilfully prevent the deterioration of their instruments by a method of this kind.

Portland cement, ordinary mortar, compositions used for sticking the parts of broken china together, all act in a similar manner—by adhesion.

There are certain curious modifications of adhesion, which have engaged the most careful attention of learned scientific men. The particular cases that will be mentioned here are those of "Osmose" and "Dialysis."

The word "osmose" is derived from the Greek *ὀσμός*, impulsion.

Dialysis (*δια* asunder, *λύσις* separation) means the separation of certain substances through the intervention of some body, such as parchment paper, through which liquid diffusion may take place.

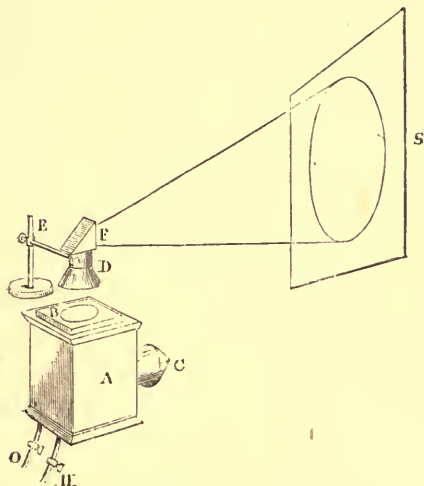


FIG. 2.

Many years ago, Dutrochet studied the passage of liquids through porous bodies, and his original instrument, called the endosmometer, has been constructed over and over again by students at medical schools, who wished to verify for themselves the remarkable fact, so suggestive of the explanation of some of the elaborate processes which go on in the economy of the human body.

Dutrochet's instrument consisted virtually of a glass funnel with a long and narrow tube. The mouth of the funnel should be ground flat, and a piece of bladder strained nicely and fixed securely over it. Into the funnel may be poured some alcohol and water, coloured blue with a little indigo; and when this is placed in a shallow vessel or plate containing water, the latter passes through the bladder and gradually diffuses into the alcohol, so that the liquid in the funnel rises, contrary to the law of gravitation, and might overflow if the tube of the funnel were not long enough. This effect is due to the fact that the bladder is more easily wetted by water than by alcohol: the water adheres to the bladder in a greater degree than alcohol, and therefore its lower surface dipping into the water in the plate, is first moistened with water. When the latter has risen by capillary attraction and filled the pores of the membrane, it has reached the upper surface where the alcohol exists; and here, by the adhesion taking place between the two fluids, the plain water and the spirit, they diffuse themselves through each other, and so the process continues, which increases the bulk of the fluid in the funnel; and as the flow is from the outside to the inside, it is called *endosmosis* (ἐνδὸν inwards, and ὥσμιος impulse); at the same time a reversal of the process is going on, by which a small quantity of the alcohol passes from the inside to the outside, and this, being exactly contrary to the other, is called *exosmosis*, outward impulse.

Whichever liquid wets the membrane most freely determines the direction of the impulse. Thus, if another funnel be covered with a membrane composed of a thin film of collodion, as the alcohol wets the latter quicker than water, the flow would be more rapid from the inside to the outside, and the former experiment with the bladder would be reversed, the liquid in the funnel falling instead of rising.

Professor Graham has taken up the subject and examined the phenomena in the most patient and laborious manner, and his experiments show that osmose depends essentially on the chemical action of the liquid, on the particular porous matter or septa used: the corrosion of the septum seems to be a necessary condition of the flow. His experiments were made with saline substances; and, as a proof of the correctness of the explanation, it was found that tanned sole-leather, though a porous substance, showed no osmose or impulse either way, because it is not acted upon by saline solutions.

To set up osmose the chemical action should be different on the two sides of the membrane, and therefore an alkaline solution on one side and an acid one on the other gave some of the best results, the flow of water being chiefly towards the alkaline or basic side. The solution should not be too strong, or the pores may become stopped by the particles of the salt.

Graham calls the rising of the fluid in the osmometer *positive osmose*; the reverse, *negative osmose*. His elaborate researches are to be found in the "Philosophical Transactions," 1854, p. 177, and "Chemical Society's Journal," Vol. VIII., p. 43.

Osmose no doubt plays a most important function in the economy of life, and promotes that combination of acids and alkalis already alluded to as the probable source of the currents of electricity in the human body.

DIALYSIS.—This department of physical attraction Professor Graham has made peculiarly his own, and, by working out the principle of liquid diffusion, has added another mode of analysis to those previously known.

He divides all soluble substances into two classes, which he terms *crystalloids* and *colloids*.

Bodies capable of crystallization, such as sugar or common salt, would belong to the first, and they are found to have a greater power of diffusive mobility through porous septa.

Substances incapable of crystallization, called colloids from *κόλλη*, glue, such as many animal substances—albumen, gelatine, or glue; or other bodies—gum, caramel, or starch, do not diffuse themselves easily through septa, and do not assume a crystalline form; they are, moreover, nearly tasteless.

The experiment can be made by stretching an insoluble colloid, such as parchment paper, over a hoop made of gutta-percha, thus forming a shallow tray. If this be floated in a porcelain dish containing distilled water, taking care that the bulk of the latter is nine or ten times that of the contents of the tray, a direct separation of a body, such as arsenious acid, may take place; and supposing a complex mixture of soup, milk, sugar, tea, beer, and arsenious acid is put into the tray, in the course of twenty-four or forty-eight hours arsenic may be detected in the water in the porcelain dish so nearly free from organic matter that the water may be evaporated to a small bulk, and the test of sulphuretted hydrogen applied at once, when the usual characteristic yellow ter-sulphide may be obtained on the addition of a little hydrochloric acid.

There are many other important separations which may be conducted in a similar manner, and the whole subject is fully discussed in Graham's paper, "Philosophical Transactions," 1861, p. 183.

CHEMICAL ACTION.

This power may refer to many changes: the combination of oxygen with iron taking place slowly in the cold dead iron railings fencing-in our dwelling-houses; the slow, the indirect, but sure attacks of the same element on the dwelling-house of the soul, the human constitution, bring about the inevitable wearing away of the vital battery—the energy that will not for ever respond to the will of the possessor; and thus old age is equivalent to rust, and the ordinary functions of the body that support life come to an end by what is spoken of in connection with dead matter as “reasonable wear and tear.” The first entry of air to the lungs of the new-born infant is proclaimed with a cry that may be repeated in another tone as the last gasp of air passes spasmodically from the lips of the departing aged.

Carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, and certain earthy and saline matters individually have characteristic properties, and all of these, with the mystery of vital force, contribute to build up the human body. How natural, then, to define “chemical action” to be that change which takes place when one or more substances unite and form another or other bodies perfectly different from those that were engaged in forming it or them.

It is chemical action that maintains the greatest of all results—vitality—whether observed in the animal or vegetable kingdom.

Mercury is a brilliant opaque fluid metal: it is sometimes called *quicksilver*, because it is difficult to catch. Chlorine is a green gas, very potent and aggressive, and these qualities render it hurtful to the lungs, and, if inhaled, it may excite a cough of a violent description. All these physical properties change when the two unite to form a white, inodorous, insipid substance, insoluble in water—a useful medicine, and commonly called calomel; and their properties change again if more chlorine is united to the mercury, when the resulting salt is found to be soluble in water, and possesses an acrid, nauseous taste that lingers long in the mouth, and is a most violent poison. It is no longer called calomel, but corrosive sublimate; *i.e.*, these are only the vulgar names: strictly speaking, science calls the former mercurious chloride, Hg_2Cl_2 , and the latter mercuric chloride, HgCl_2 .

Chemical action or attraction is, therefore, a subtle power possessing wondrously energetic qualities capable of operating on the minutest particles of matter, at distances that the most refined means cannot measure.

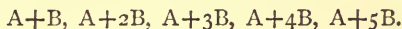
There are laws that rule chemical attraction, as with the other forces, such as electricity, magnetism, &c.

I. *Definite Proportions*, viz., all elements uniting with other elements, combine in certain fixed and invariable proportions, as shown in the table, page 16. The composition of pure water cannot vary: it may be the product of a thousand different changes, but its constituents are fixed to certain proportions,—the weight of the oxygen is always eight times that of the hydrogen.

II. *Multiple Proportions*.—When one body enters into combination with another in different proportions, the numbers indicating the greater proportion are simple multiples of that denoting the smaller proportion.

1. Nitrous oxide contains 28 parts nitrogen to 16 of oxygen.				
2. Nitric oxide	"	28	"	32
3. Nitric trioxide	"	28	"	48
4. Nitric tetroxide	"	28	"	64
5. Nitric pentoxide	"	28	"	80

We may paraphrase the above, and put it thus:



III. *Equivalent Proportions* result from Law I., and every element displacing another does so in fixed numerical proportions. Knowing the combining weight of mercury, and supposing it to be united with an atom of iodine, it is easy to see, by looking at the table of atomic weights (page 16), what proportion of chlorine would be required to replace one atom of iodine, or how much calcium would be required to replace magnesium if the former were separated from its atomic or combining proportion of sulphuric acid.

IV. Gaseous or æriform bodies combine in proportions which can be ascertained by exact volumes having a very simple relation to each other.

The ratios may be 1 volume of A to 1 of B, *i.e.*, the gases may unite in equal volumes; or 1 of A to 2 of B; or 1 of A to 3 of B; or sometimes 2 of A to 3 of B.

In the combination of any two gases by volume, this simple proportion is usually observed.

An atomic weight of any particular substance, when converted into the gaseous state at the same temperature and pressure, always yields the same volume.

1 gramme of hydrogen at 32° F. and 29.92 in. barometer, <i>i.e.</i> ,				Litres.
0° C. and 760 millimètres }				=11.19
16	"	oxygen	"	"
35.5	"	chlorine	"	"
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In the above it will be seen that equal volumes give a variety of weights, 11.19 litres of hydrogen weighing only 1 gramme, and 11.19 litres of chlorine weighing 35.5 grammes. If this arrangement of volumes and weights is reversed, and equal weights are taken of the above-named elements, it is evident that the volumes will differ. So that the difference between combinations by weight and volume must always be remembered in chemical combinations.

2 gases in equal volumes, represented by two squares, may unite				Volumes.
and form				2 ☐
3 volumes may be condensed into				2 ☐
3	"	"	"	1 ☐
2	"	"	"	1 ☐

The like reasoning applies to compound gases and vapours, which unite in the same simple ratio of volumes with reference to their atomic weights.

It does not seem to be possible to create a large volume, or increase the bulk, of any given volumes of gases that combine with each other. There is thus a constant relation between the atomic weights and volumes of bodies in the gaseous or vaporous state.

NOMENCLATURE.

Before chemistry existed as a science, substances received their names from their real or supposed properties, or from some circumstance connected with their production. Thus phosphorus is derived from two Greek words $\phi\omega\varsigma$ and $\phi\epsilon\rho\epsilon\iota\nu$ (to bear light). The name anamonia is said to be derived from its being produced in quantity by the decomposition of animal matter around the temple of Jupiter Ammon. Potash also received its name from the ancient means of procuring it. This was effected by burning wood in open iron "pots:" the ashes were hence called "pot-ashes."

Some substances were named after the stars and planets, as lunar caustic, *i.e.*, nitrate of silver; mercury, quicksilver. Thus we see the names of most substances were given in an unsystematic manner.

To the elements recently discovered some attempt has been made to give names with like terminations to those elements which resemble one another. Thus three elements ending in *on*, and resembling each other in properties in some respects, are carbon, boron, and silicon.

Chlorine, bromine, iodine, and fluorine form another group resembling one another, and all terminating in *ine*.

The termination *um* is indicative of a metal, as sodium and potassium; and if the Latin names be used, all the metals will be found to end in *um*, as ferrum (iron), plumbum (lead), argentum (silver), &c. With the exception of selenium, no non-metal terminates in *um*.

It is the object of chemical nomenclature not only to name substances, but also through their names to give the knowledge of the elements of which they are composed, and, as far as possible, their proportion.

Speaking of classification and nomenclature, Dr. Hofmann, in the preface to his "Modern Chemistry," says: "The domain of chemical philosophy has, for many years past, rather resembled a tumultuous battle-plain than a field bestowed by Nature for peaceful cultivation by mankind." And a learned critic in the "Athenæum," alluding to that passage, remarks: "But there are many thoughtful observers who, looking upon that cultivated domain, are disposed to believe that the flowers are likely to be choked by weeds, in the shape of an endless number of hypothetical radicals, most complex formulæ, and an unpronounceable nomenclature. On the first introduction of the new chemical philosophy, Herschel explained his objections to the alteration of the term muriatic acid into hydrochloric acid. The evils which he then foresaw have been more than realized, and the literature of chemistry is now deformed with such names as platino-cyanide of diplatosammonium, cymyl-dithionite of sodium, bromide of triammo-dicu-pro-diammonium, and formulæ extending across an octavo page; so that a treatise of chemistry has very much the appearance of a book written in an unknown language. 'It is not necessary to the progress of this science,' write two eminent modern chemists, 'that its language should change with the opinions of every new theorist. . . . They have apparently been engaged in working out an idea, and seeking for some

Utopian standard of perfection in a new system of notation; but in endeavouring to settle contested points on a firmer basis, they have incurred the risk of unsettling everything.”

When two elements unite together they form what is called a binary compound, such as oxide of zinc, or zincic oxide. This name gives at once the knowledge that the compound consists of two elements, zinc and oxygen, one equivalent of each being in the compound.

The non-metallic elements combined with each other, or with the metals, form the principal binary compounds.

In the following table* is shown the nomenclature of binary compounds: the symbols of the compounds are in the fifth column.

The Compounds of	Are termed	For example :		Or in Symbols,
		or		
Oxygen	Oxides	Zincic oxide	Oxide of zinc	ZnO
Chlorine	Chlorides ...	{ Argentichloride	Chloride of silver	} AgCl
Bromine	Bromides ...	{ Sodichloride	Bromide of sodium	} NaBr
Iodine	Iodides	{ Potassic iodide	Iodide of potassium	} KI
Fluorine	Fluorides ...	{ Potassic fluoride	Fluoride of potassium	} KF
Nitrogen	Nitrides	Boric nitride	{ Nitride of boron	} BN
Carbon	{ Carbides or Carburets	Nitric carbide (cyanogen)	Carbide of nitrogen	} CN
Sulphur.....	{ Sulphides or Sulphurets	{ Cupric sulphide	{ Sulphide of copper	} CuS
		{ Plumbic do.	{ Sulphuret of lead	} PbS
Selenium	{ Selenides or Seleniurets	{ Mercuric selenide	Selenide of mercury	} HgSe
		{ Cadmic do.	{ Seleniuret of cadmium	} CdSe
Phosphorus	{ Phosphides or Phosphurets	{ Calcic phosphide	Phosphuret of calcium	} CaP

In employing symbols, the symbol of the basylous or electro-positive element is generally placed first.

When the same elements unite in various proportions, Latin or Greek numerals are used as prefixes to distinguish between the different compounds of the same elements. Thus the first oxide of ruthmium is called the protoxide, RuO; the second oxide is called the deutoxide, RuO₂; the third is named the trioxide, RuO₃.

The name *binoxide* is applied to the oxide that contains twice as much oxygen as the protoxide.

* From Miller's "Elements of Chemistry," Part II.

The prefix *sesqui* is given to compounds which contain two elements in the proportion of 3 to 2, or $1\frac{1}{2}$ to 1, as sesquioxide of ruthmum, Ru_2O_3 . The prefix *per* signifies the highest combinations, as perchloride of mercury.

Many oxides form, when united with the elements of water, acids.

Some bodies have two or more oxides, which form, with the elements of water, acids; and in order to distinguish between them a certain nomenclature is made use of. Thus the name of the acid containing the largest proportion of oxygen terminates in *ic*, as sulphuric acid, H_2SO_4 , and that with the less amount ends in *ous*, as sulphurous acid, H_2SO_3 .

An acid has sometimes been discovered containing a larger proportion of oxygen than the one to which the termination *ic* had been given. Then the prefix *per* has been used to denote this, as chloric acid HClO_3 , and perchloric acid, HClO_4 .

An acid containing less oxygen than the one ending in *ous* has the prefix *hypo*, as chlorous acid, HClO_2 , hypochlorous acid, HClO .

Besides these acids which contain oxygen, there are others which contain no oxygen; for instance, hydrogen and chlorine combine to form hydrochloric acid, HCl ; also hydrogen and iodine form hydriodic acid, HI .

In the naming of the oxysalts—the union of an oxyacid with a base—the name of the salt containing the acid with the largest proportion of oxygen terminates in *ate*, as the compound of sulphuric acid and soda is called disodic sulphate, or sulphate of sodium, Na_2SO_4 ; whilst the salt of the acid containing less oxygen, and terminating in *ous*, ends in *ite*, as the compound of sulphurous acid and soda is named disodic sulphite, or sulphite of sodium, Na_2SO_3 .

When a metal forms more than one basic oxide, *i.e.*, more than one oxide capable of forming salts by the action of acids, the name of the metal in the oxide containing the smaller proportion of oxygen ends in *ous*; and in the oxide containing the larger amount of oxygen it terminates in *ic*, as in the case of iron.

The protoxide is called ferrous oxide, FeO , and the salts of this oxide ferrous salts, as ferrous sulphate, FeSO_4 (+7 H_2O , water of crystallization).

The sesqui oxide is termed ferric oxide, Fe_2O_3 , and its salts ferric salts, as ferric sulphate, $\text{Fe}_2(\text{SO}_4)_3$.

Most chemists of note now look upon acids as salts of hydrogen, the latter representing the metallic part. And when these hydrogen salts act upon other metals, they look upon the reaction as a replacement of hydrogen. There is no doubt that this system is quite consistent, and much more in accordance with observed facts, than the older ideas, which are daily losing ground.

When a molecule of an acid contains one atom of hydrogen capable of being replaced by one atom of a monad metal, it is called a monobasic acid, such as nitric acid, HNO_3 , the hydrogen of which can be replaced by one atom of the monad metal potassium. If it contain two atoms of replaceable hydrogen, it is called dibasic, such as sulphuric acid, H_2SO_4 , the two atoms of hydrogen which it contains being replaceable by two atoms of a monad metal like potassium, or one atom of a dyad metal such as copper. Those bodies which contain more than one atom of replaceable hydrogen are called polybasic.

The terms monad, dyad, triad, tetrad, pentad, and hexad are used to denote the equivalents of the different elementary bodies in compounds as compared with hydrogen.

If we compare the equivalents of the elements in compounds with hydrogen, we find that they differ very much in value. Thus;

The monad potassium is equivalent to 1 atom of hydrogen in a compound.
 The dyad zinc " 2 atoms of " "
 The triad bismuth " 3 " "
 The tetrad platinum " 4 " "
 The pentad nitrogen * " 5 " "
 The hexad manganese " 6 " "

TABLE OF THE SYMBOLS, AND NEW AND OLD COMBINING OR
 ATOMIC WEIGHTS OF THE ELEMENTS.

NAMES OF ELEMENTS.	SYMBOL.	NEW At. Wt.	OLD At. Wt.	NAMES OF ELEMENTS.	SYMBOL.	NEW At. Wt.	OLD At. Wt.
Aluminium ...	Al	27.4	13.7	Molybdenum..	Mo	96.0	48.0
Antimony.....	Sb	122.0	—	Nickel	Ni	59.0	29.5
Arsenic.....	As	75.0	—	Niobium	Nb	94.5	—
Barium.....	Ba	137.0	68.5	Nitrogen	N	14.0	—
Bismuth	Bi	210.0	—	Norium.....	No	—	—
Boron	B	10.9	—	Osmium	Os	199.0	99.4
Bromine	Br	80.0	—	Oxygen.....	O	16.0	8.0
Cadmium.....	Cd	112.0	56.0	Palladium.....	Pd	106.5	53.25
Cæsium	Cs	133.0	—	Phosphorus ...	P	31.0	—
Calcium	Ca	40.0	20.0	Platinum	Pt	197.2	98.56
Carbon	C	12.0	6.0	Potassium ...	K	39.1	—
Cerium	Ce	92.0	46.0	Rhodium	Rh	104.2	52.1
Chlorine	Cl	35.5	—	Rubidium.....	Rb	85.3	—
Chromium ...	Cr	52.5	26.25	Ruthmium ...	Ru	104.2	52.1
Cobalt	Co	59.0	29.5	Selenium	Se	79.5	39.75
Copper	Cu	63.4	31.7	Silicon	Si	28.0	14.0
Didymium ...	D	96.0	48.0	Silver	Ag	108.0	—
Erbium.....	E	114.6	—	Sodium.....	Na	23.0	—
Fluorine	F	19.0	—	Strontium.....	Sr	87.5	43.8
Glucinum.....	Gl	9.4	4.7	Sulphur.....	S	32.0	16.0
Gold	Au	196.6	—	Tantalum.....	Ta	137.6	68.8
Hydrogen ...	H	1.0	—	Tellurium.....	Te	129.0	64.5
Indium	In	74.0	—	Thallium	Tl	204.0	—
Iodine	I	127.0	—	Thorium	Th	115.7	59.5
Iridium.....	Ir	197.2	98.6	Tin	Sn	118.0	59.0
Iron	Fe	56.0	28.0	Titanium	Ti	50.0	25.0
Lanthanium..	La	92.0	—	Tungsten	W	184.0	92.0
Lead	Pb	207.0	103.5	Uranium	U	120.0	60.0
Lithium	Li	7.0	—	Vanadium ...	V	137.0	68.5
Magnesium ...	Mg	24.3	12.15	Yttrium.....	Y	61.7	—
Manganese ..	Mn	55.0	27.5	Zinc	Zn	65.0	32.5
Mercury	Hg	200.0	100.0	Zirconium.....	Zr	89.5	44.75

The above is a list of the elements at present known to chemists, with

* Usually triad, sometimes pentad.

their symbols, and their new and old combining or atomic weights. As it would be inconvenient, in expressing chemical reactions in writing, to write the whole name of an element, the first or first two letters of the name are used as symbols to denote any particular element; thus O stands for oxygen, H for hydrogen, Co for cobalt. In the case of some metals, the first and prominent letters of the Latin name are used as symbols, as Ag for silver (argentum), Pb for lead (plumbum). The first two letters of the name of an element are used as its symbols when there is another element beginning with the same letter. Thus C is used as the symbol of carbon, and Cl is used for chlorine, in order to distinguish between the two. The symbol of an element when used by itself not only stands for that element, but also for a certain proportion thereof by weight, called its atomic weight; such proportion being the smallest proportion by weight in which such element combines with, or is eliminated from, a chemical compound, hydrogen being taken as unity.

Thus C does not stand merely for carbon, but also for exactly 12 parts by weight of carbon, or O stands for 16 parts of oxygen.

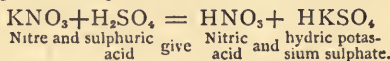
The small figure placed to the right hand of the symbol of an element signifies the number of atoms of that element. Thus C_4 means 4 atoms, or 4×12 parts of carbon; O_2 means 2 atoms, or 2×16 parts of oxygen.

The symbols of compounds are made by placing the symbols of the elements forming the compounds side by side, as

Water	.	.	.	.	.	H_2O
Sulphuric acid	.	.	.	.	.	H_2SO_4
Ammonia	.	.	.	.	.	H_3N

When more than one molecule of a compound has to be denoted, a large figure is placed to the left hand of the formula of the compound, and all the symbols in the formula are multiplied by the large figure which stands before it; thus $2H_2O$ means two molecules of water.

Chemical reactions are expressed by equations. The symbols of the elements before the change are placed on one side of the equation, and the symbols representing the change effected on the other, thus:



It is necessary to distinguish clearly between the terms *atom* and *molecule*. An atom means something which cannot be further subdivided. And thus, in the table of elements (p. 16) O stands for one atom of oxygen, H for one atom of hydrogen. A molecule may contain more than one atom, as, for instance, H_2 : this would be called a molecule containing two atoms of hydrogen; H_2O would be a molecule of water; and H_2O_2 a molecule of peroxide of hydrogen or hydric peroxide, or oxygenated water. These expressions are most important, and prevent the confusion of the term "atomic" with that of "equivalent," because they are quite different from each other. A *molecule* is very properly defined by Roscoe to be "the group of atoms forming the smallest portion of a chemical substance, either simple or compound, which can exist in the free state." And he gives a good illustration of the difference between *atomic* and *molecular* formulæ in the following: $H + Cl = HCl$ is the atomic expression, whilst $H_2 + Cl_2 = 2HCl$ is the molecular expression for the same reaction.

ELEMENTS WHICH ARE NOT METALLIC.

OXYGEN.

Symbol, O. Atomic weight, 16.

In the month of August, 1774, Dr. Priestley discovered this important element, and Mr. George Rodwell has very properly insisted, in a learned paper in the "Chemical News," that it was not discovered by Swedenborg half a century before Priestley, and that there is not a particle of reliable evidence in support of this statement. "We are quite unable," says Mr. Rodwell, "to comprehend by what contortion of the meaning of the principal passage quoted, Swedenborg can be supposed to allude to oxygen. 'Air,' he writes, 'consists superficially of fifth finites, and within it are enclosed the first and second elementaries.' And again: 'The fifth finites have entered into the surface of the ærial particle, and the first and second elementaries into the internal space.' There is no possible reason for assuming that by the meaningless term 'fifth finites' oxygen gas is alluded to; and if there were any evidence at first sight, it would be speedily nullified by the fact that Swedenborg afterwards speaks of *crystals* of this matter. It is useless to pursue the subject further: the only evidence in support of the supposition is so utterly shallow that it is not worthy of criticism, for it carries with it its own refutation."

Dr. Priestley obtained the first oxygen produced from "red precipitate," (the red oxide of mercury) by heating it at a temperature of 752° F.—expressed in symbols, HgO —yield $\text{Hg} + \text{O}$.

Lavoisier, in his "Elements of Chemistry," says this "species of air" was discovered about the same time by Dr. Priestley, Mr. Scheele, and "myself."

In a pamphlet, published in 1800 by Priestley, after his return to America, he says, "Having made the discovery some time before I was in Paris in the year 1774, I mentioned it at the table of M. Lavoisier, when most of the philosophical people in the city were present, saying it was a kind of air in which a candle burned much better than in common air, but I had not then given it any name. At this all the company, and M. and Madame Lavoisier as much as any, expressed great surprise. I told them I had gotten it from *precipitate per se*, also from *red lead*. Speaking French very imperfectly, and being little acquainted with the terms of chemistry, I said *plomb rouge*, which was not understood until M. Macquer said I must mean *minium*. Mr. Scheele's discovery was certainly independent of mine, though, I believe, not made quite so early."

Scheele obtained oxygen from one of the minerals of his own country as he happened to be investigating the nature of the ores of manganese.

Lavoisier, with the quickness of wit belonging to his countrymen, does not appear to have been slow in verifying Priestley's experiment, which was *analytical*. Great credit is due to Lavoisier for reversing Priestley's experiment, and making it *synthetical*: by subjecting a given quantity of air to the action of boiling quicksilver, he made that which Priestley decomposed—viz., red precipitate.

The latter called oxygen Dephlogisticated Air. Lavoisier gave the element a name which has remained, like an official registry of a baptismal name, to the present time. He called it Oxygen ($\alpha\gamma\epsilon\upsilon\varsigma$ acid, $\gamma\epsilon\rho\rho\alpha\omega$ to produce), while others styled it Empyreal, or Vital Air.

One method of preparing oxygen gas has already been mentioned, viz., that of heating the red oxide of mercury. This may be easily done in a test-tube, and the escape of the oxygen gas is soon rendered evident by a splinter of wood inserted, with the end carbonized and just red hot or glowing, which immediately bursts into flame with a sort of explosion, and then burns with great brilliancy.

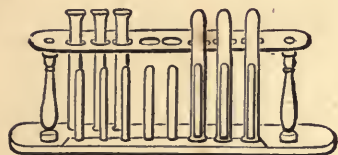


FIG. 3.—Test-tubes and Rack.



FIG. 4.—A Quicksilver Bottle of wrought iron, used for heating the black Oxide of Manganese.

With respect to the chemical apparatus that may be described in this section, the reader is recommended to go to Mr. How, Foster Lane, Cheapside, where every kind of chemical apparatus may be obtained.

At the Polytechnic, where oxygen is used in very large quantities for the oxy-hydrogen light, it is made by heating the black oxide of manganese, MnO_2 , in wrought-iron bottles.

Three equivalents of MnO_2 yield the red oxide Mn_3O_4 , and two equivalents of oxygen gas. The plug is taken out of the iron bottle, and an iron pipe screwed into it: this is connected with a large flexible tube, and, first bubbling through a simple washing apparatus, the gas passes direct to a large copper gasometer. Good black oxide of manganese is worth about £9 a ton, and should yield one-ninth of its weight of oxygen gas. It very rarely happens that the mineral affords more than half that quantity. At the Polytechnic an average of eight tons are used during the year; one-sixteenth of this, viz., ten cwts., will represent the weight of oxygen used in that establishment.

On the small or the large scale, where cost is of little consequence, oxygen is readily procured by heating potassic chlorate (chlorate of potash), not alone, because the heat softens the glass vessel, but mixed with one-third or one-

fourth of black oxide of manganese. The oxygen escapes at a temperature of 450° or 500° F., and the black oxide of manganese undergoes no decomposition. One ounce of the chlorate will yield about two gallons of oxygen— $2\text{KClO}_3 = 2\text{KCl} + 3\text{O}_2$.



FIG. 5, 6, 7,—A Ring Stand, with reducing Porcelain Ring, to support, if necessary, the Flask.

The flask containing the chlorate mixture is fitted with a cork and bent tube, and heated by a spirit-lamp, or by any of the convenient gas-burners which consume mixed air and coal-gas.

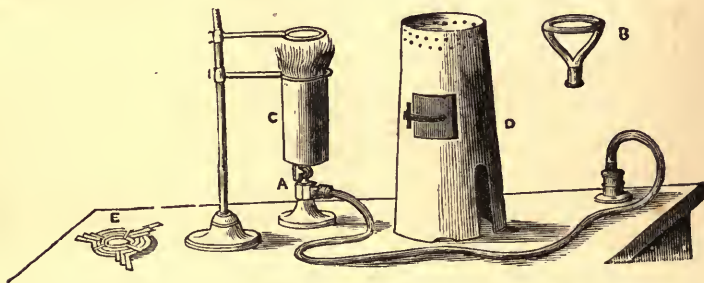


FIG. 8.—Various Gas-burners used for heating purposes.

A, mixed gas and air burner, with wire gauze at the top of the chimney, C; sheet-iron case, D, for protecting a gas or spirit-flame from currents of air and economizing heat; B, a ring perforated with holes for burning gas; E, rings of wire for reducing the size of the large rings of the ring stand, in order to support smaller vessels.

The oxygen gas may be collected in jars placed upon the shelf of the very convenient tank of water called a Pneumatic Trough.

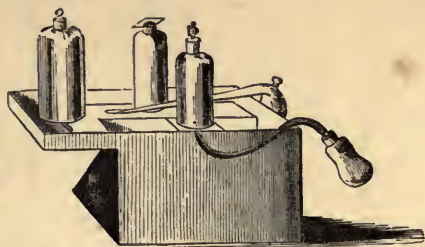
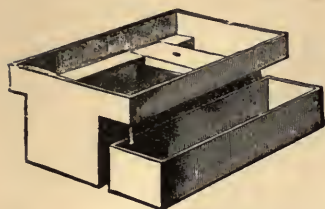
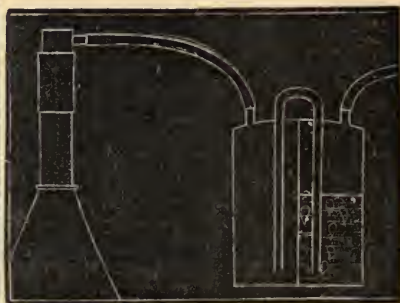
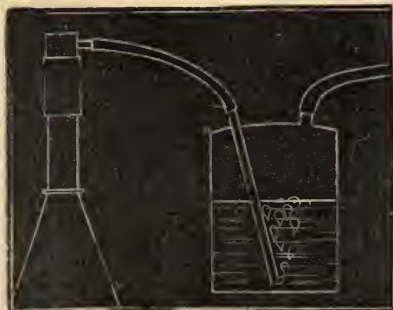


FIG. 9.—*A Pneumatic Trough.* FIG. 10.—*Pneumatic Trough in use.*

In the above, Fig. 9, another box is provided, to receive any overflow and to prevent the slopping of water on the table where the experiments are conducted. The ordinary pneumatic trough, with the gas-jars on the shelf, and the flask and tube or retort containing the substance yielding gas, is shown in Fig. 10.

When large quantities of oxygen are required for the oxy-hydrogen lantern, the gas is conveniently and quickly made from the chlorate mixture by placing it in a thin sheet-iron vessel made in the form of a cone: the latter can be placed over a larger ring of burning gas or on an open fire; and by taking the precaution to pass the oxygen first through a wash-bottle containing a little slaked lime and water, a great deal of the chlorine produced from the decomposition of the potassic chlorate is absorbed. If the chlorine be not



FIGS. 11, 12.—*Highley's arrangement for making and washing the Oxygen Gas.*

removed with lime, or, better still, with potash, it soon acts upon the brass taps fixed into the caoutchouc bags; and when—perhaps at a critical moment—a good light is wanted, the tap is stopped up, and the microscopic slide or the magic lantern picture is badly lighted.

In the article on the dissolving view apparatus Mr. Samuel Highley, of 10



FIG. 13.—*Gas Generator, Spirit-lamp, Ring Stand, Wash Bottle, and Gas-bag.*

Great Portland Street, has been recommended for all apparatus of that kind; and another simple arrangement of a thin sheet-iron or copper bottle containing the chlorate mixture, attached by flexible tubes to a simple washing apparatus made with a corked bottle, into which the pipe from the generator dips, with a delivery-pipe passing to an india-rubber bag, is shown at Fig. 13.

There are many other ways in which oxygen can be made, all detailed in works devoted to chemistry, such as Dr. Miller's "Elements of Chemistry," or Abel and Bloxam's "Handbook."

THE PROPERTIES OF OXYGEN.

The specific gravity of this gas is 1.10563: it is perfectly tasteless, odourless, and colourless, and has never been reduced by extreme cold or great pressure into the liquid or solid condition; oxygen is therefore said to be a permanent gas. With the exception of fluorine, oxygen unites with every other known element.

Charcoal, sulphur, phosphorus, many of the metals, such as iron, zinc, potassium, and sodium, burn in this gas with great brilliancy, forming acids, oxides, and alkalis.

The act of dissolving a metal in nitric acid is called oxidation, the acid yielding oxygen to the metal, which oxide afterwards unites with another portion of the acid.

Liquid red hot nitre acts as a powerful oxidizer, in which the hardest form of carbon, viz., the diamond, is readily oxidized and dissolved, by forming carbonic anhydride, which unites with the dipotassic oxide or potash— K_2O .

One hundred cubic inches of oxygen, at 60° and 30 in. barometer, weigh 34.203 grains. Water dissolves a small volume of oxygen gas.

100 volumes of water dissolve 4.11 volumes of oxygen at 32° F.

100 " " 2.99 " " 59° "

REMARKS.

It has been ascertained that oxygen possesses weak but decidedly magnetic properties, like those of iron, liable to diminution or increase by raising and lowering the temperature. Oxygen is a dyad, as in H_2O , in common with sulphur, selenium, and tellurium.

The atomic weight of oxygen is now taken as 16 instead of 8, so that water is represented by the formula $H_2O=18$ instead of 9.

Oxygen represents nearly one-fifth of the bulk of the atmosphere, the component parts of which will be considered hereafter.

Every nine pounds of water contain eight of oxygen.

Nearly half the weight of dry sand and clay consists of oxygen.

The vital functions cannot be maintained without oxygen, and by a species of slow combustion, or oxidation of the blood through the ramifications of the lung process, heat is slowly produced; and that a new product is formed is shown by the quantity of carbonic anhydride expired with the breath, and the change of the dusky purple or dark blood to bright crimson.

There is no gaseous body more serviceable and important to man, or any element which has helped to increase the industrial wealth of this country so much as oxygen.

The various compounds it forms, such as oxides, acids, basic oxides, alkalies, and saline oxides, will be referred to in other places.

The tests for oxygen are combustion with hydrogen and formation of water.

The change of colour when a solution of pyrogallic acid in potash is shaken with oxygen.—The solution of potash alone will not dissolve oxygen, but the pyrogallic acid determines the rapid absorption of this gas and turns a dark brown colour.

A mixture of colourless nitric oxide gas, NO , with oxygen, forms red fumes, which are readily soluble in water.

OZONE.

Although oxygen has never been changed from the gaseous state to a liquid or solid condition, it seems to be capable of assuming a peculiar condensed form called Ozone,—a word taken from the Greek $o\zeta\omega$, to give out an odour.

MM. de Babo, Claus, and Soret all maintain that ozone is oxygen denser than common oxygen gas. The latter philosopher especially declared that ozone as a molecule consisted of three atoms of oxygen, and he therefore called it *binoxide of oxygen*. M. Soret, in continuation of his researches on the density of ozone, and employing the absorptive powers of essences of turpentine and cinnamon, has come to the conclusion that the density of ozone is $1\frac{1}{2}$ times that of oxygen, and gives as the formula for ozone O_3 . Other learned chemists appear to concur in this opinion.

Ozone is produced in various ways.

1. By passing a series of electrical discharges—silent ones—through dry oxygen gas: the latter diminishes in bulk to the extent of one-twelfth, showing condensation; and if subsequently heated to a temperature of 550° F., re-

covers its former bulk and loses its peculiar ozone qualities. The reason the electrical discharge should be a silent one is because the electrical spark produces too much heat, which destroys a considerable portion of the ozone, and thus prevents any considerable accumulation. At p. 40 Siemen's apparatus is described (an induction apparatus), by which large quantities of oxygen may be converted into ozone.

2. This peculiar condition of oxygen is obtained by acting either on potassium permanganate (KMnO_4) or upon baric dioxide (BaO_2) with strong sulphuric acid.

3. A stick of phosphorus scraped clean under water, and then exposed in a bottle containing moist air, produces ozone.

4. When water is decomposed in the apparatus called a voltameter, the mixed gases give the peculiar odour and are found to contain a certain quantity of ozone.

The best tests for this condensed form of oxygen are potassium iodide, and starch paste painted with a brush on paper, or paper dipped in a solution of sulphate of manganese, $\text{MnSO}_4 + 5\text{H}_2\text{O}$. The first turns blue from the liberation of iodine and the formation of a blue compound of starch and iodine; and the second indicates the presence of ozone by the formation of the brown hydrated peroxide of manganese.

Schönbein, who first directed attention to this allotropic condition of oxygen, directs the test-paper to be made of a fixed strength, by dissolving one part of pure potassic iodide in 200 parts of distilled water, which is then to be thickened by heating it with 10 parts of starch. This solution is to be applied to bibulous paper, which, when dry, should be kept in a stoppered bottle covered with tin foil, in order to exclude the light.

It is known that sea-air contains ozone, whilst the same air, having passed over or through a town, is supposed to be deprived in a great degree of this agent, which is considered to have purifying and health-giving powers. The absence of ozone from the air is said to be prejudicial to health, and during the prevalence of cholera it was thought to be due in some degree to the absence of this condition of oxygen.

Dr. Daubeney found, in the three winter months commencing with January, at Torquay, that the south-west and westerly winds were most fully charged with ozone, whilst the north winds showed the least. On the contrary, at Oxford during the summer months of the same year, the easterly winds were most charged with ozone, and the north-westerly the least. These indications clearly pointed to the influence of the sea in augmenting the amount of ozone at Torquay, whilst the more central inland position of Oxford caused the difference between the maximum and minimum indications to be much less apparent than at the sea-side. Daubeney also found that plants growing in the sunshine liberate a body that affects the starch test like ozone, and hence inferred that this remarkable property of plants might have something to do with the maintenance of the healthiness and purity of the air.

Ozone possesses most energetic qualities. It sets free iodine from its combination with the metals. Black sulphide of lead or plumbic sulphide (PbO) is attacked by ozone; the black stain disappears, and both the sulphur and the lead oxidize, the white sulphate of lead (PbSO_4) being produced. Ozone is a powerful bleaching agent: it irritates the lungs if inhaled in any quantity; and this is not surprising when it is remembered that both cork and caoutchouc are not proof against its oxidizing power. Silver, which resists common

oxygen, and is so often used in chemical processes for this reason, is converted into peroxide when exposed to the action of ozone, provided that the presence of moisture is secured.

Ozone is now introduced into certain chemical processes, and is likely to take a very prominent place as one of the oxidizers, the wealth-producers in refining sugar, bleaching calico, &c.

NITROGEN.

Symbol, N. Atomic weight, 14.

Nitrogen is described in an old work as “a simple oxidable body, by some chemists called *azot*, from its property of destroying life. This name appears improper, since several other gases have the same effect on animals.” It was discovered by Dr. Rutherford in the year 1772, and was called Nitrogen from *νιτρον* nitre, and *γεννω* to generate.

It would be difficult to speak of nitrogen without alluding to the important part it takes in the composition of the atmosphere. Rodwell says, from the continued observation that the cessation of breathing was the cessation of life, the belief became prevalent that the soul passed from the body with the last expiration of air; hence the expressions, “*Eflare animam*,” “*Exhalare animam*,” “*Expiram animam*.” Again, *πνευμα*, *spiritus*, *anima*, have each the triple meaning of *soul*, *breath*, *wind*. There is also a Hebrew word having the same meaning as the Greek *pneuma*, viz., soul, breath, wind. The most convenient mode of preparing nitrogen is by removing the oxygen from atmospheric air, and when this is done it is found that it constitutes four-fifths of any given bulk. A variety of processes may be employed for this purpose, but the simplest plan is to place some dry phosphorus in a German porcelain cup, and having properly supported it on the shelf of the pneumatic trough, a long unstoppered gas-jar graduated into five equal parts is placed over the whole; a heated wire is now inserted, and directly it touches the phosphorus, the latter ignites, and the stopper of the jar is quickly inserted. At first expansion occurs, and therefore the depth of water should be adjusted beforehand, so as to allow the heated air to increase in volume without bubbling out and escaping from the bottom of the jar.

If the above manipulations are skilfully performed, very little air is lost: the phosphorus burns, producing the white fumes of phosphoric pentoxide, which gradually subside, and are dissolved, by the water. The residual gas, when cold, is found to be equal to four-fifths of the original bulk, one-fifth—viz., the oxygen—being removed by combining with the phosphorus.

The same result is more accurately obtained by thrusting up into a graduated tube containing atmospheric air a piece of phosphorus supported in a coil of platinum wire: after two or three days the phosphorus may be removed, and the remaining gas is found to be nearly pure nitrogen; and if 100 measures of air be used, 20 will be removed and 80 left.

Another mode of preparing nitrogen is by passing air over finely divided metallic copper at a red heat. The experiment conducted by Dumas and Boussingault was performed by them with great precautions in the exact analysis of air, and they found that 100 parts, by weight, of air from which the aqueous vapour, carbonic anhydride, and ammonium had been removed,

contained 77 parts of nitrogen and 23 parts of oxygen; or, more precisely, taking the average of a number of experiments,—

	Weights.	Volumes.
Nitrogen	76'99	79'19
Oxygen	23'01	20'81
	100'00	100'00

Nitrogen has no colour, taste, or smell. It is lighter than oxygen gas, and slightly lighter than atmospheric air: 100 cubic inches at 60° F., 30 in. bar., weigh 30'119 grains. A lighted taper immersed in this gas is immediately extinguished, no incandescent snuff remaining. It must not, however, be supposed that nitrogen is poisonous: it simply destroys life in the absence of oxygen gas, and cannot be poisonous, or we could not continue to breathe air, which is a mechanical mixture of the two gases always maintained in the same relative volumes by one of those wonderful conservative powers of Nature represented by the vegetable kingdom. Although the two gases differ in weight, they never separate; and by the law of the universal diffusion of gaseous bodies, they have the power of incorporating perfectly with each other; and this property of gases in general, and specially in this case, has, no doubt, the most important bearing on the purity and healthiness of the air. No combination occurs between the oxygen and nitrogen contained in atmospheric air, although it is quite possible to conceive that where ozone is produced in hot climates with certain peculiarities of soil—as in Spain, Egypt, and India—that there the nitrogen is attacked by the condensed oxygen ozone, and nitrates produced.

Professor Graham has shown that the velocity of the diffusion of the various gases is in the inverse ratio of the square roots of their densities; and, as before stated, this principle of diffusion explains why the composition of 100 parts by volume of the air may be taken at an average as follows:

Country air.	{ Nitrogen	77'95	
	{ Oxygen	20'61	
	{ Carbonic anhydride (carbonic acid)	'04	
	{ Aqueous vapour	1'40	
	{ Hydric nitrate (nitric acid)		} traces
	{ Ammonia		
Town air also	{ Carburetted hydrogen		
	{ Sulphuretted hydrogen		} traces,
	{ Sulphurous anhydride		
		100'00	

HYDROGEN.

Symbol, H. Atomic weight, 1.

Although this article on Chemistry must necessarily be confined to certain limits, and therefore the various compounds formed by the combination of the different elements cannot all be considered, exceptions to this rule must occasionally be made; and having considered the chemical nature of air, it would be hardly possible to avoid making some remarks on the constitution of water, the more so as this is the chief source from which hydrogen is obtained.

Water is presented to us in nature having different degrees of purity; hence we speak of hard or soft water. The former may contain calcium carbonate and sulphate, magnesium carbonate and sulphate, sodium sulphate and chloride, and many other substances, in considerable quantities, especially if the water flowing into the well be derived chiefly from surface drainage. When the water—such as rain-water—has been collected after several hours' rain, it is almost in a state of purity, containing then only certain gaseous matters in solution: such water is usually called soft, because it is free from the salts already mentioned. If the rain-water be collected after a long drought, it may then contain nitrates and salts of ammonium, and, if near the sea-side, would always contain sodium chloride or common salt.

River-water usually comes under this denomination, because it contains a less proportion of saline matters in solution: it is not, however, so good to drink as spring-water, because it frequently occurs that rivers receive the sewage of large towns, and hence the water contains organic matter in solution, and, should the water be taken whilst this organic matter is undergoing decomposition, very serious consequences may result to the person drinking it. It is now, however, a rule in sanitary matters to endeavour to divert the sewage from our noble rivers when possible, and with the help of proper filters the Thames water is now potable and wholesome.

All rivers flow into the sea, hence sea-water contains a larger quantity of sodium chloride, and many other salts, in solution, likewise organic matter; but, curious to say, it remains in a uniform condition so far as the quantity of saline matter is concerned, and the specific gravity varies little, the mean being 1,027, pure water being 1,000.

When sea-water or any other hard water is placed in a still and boiled, the earthy or saline matters are left behind, and, the steam only being condensed, pure water is obtained.

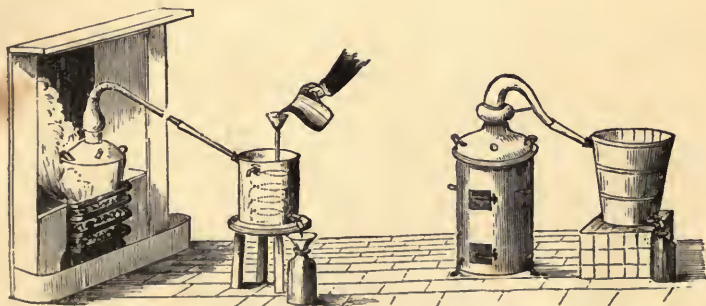


FIG. 14.—*The Still placed on a common fire or fitted to a proper furnace.*

Both the stills have worm tubs or condensers.

The operation of distilling may be performed on a very small scale by using a little flask fitted into a bent tube, which is placed in a basin containing cold water (Fig. 15). Very convenient little tin or copper stills are made by Mr. How, of Foster Lane, Cheapside: they are heated by a Bunsen burner, and will supply a sufficient quantity of fresh distilled water for any analytical operations con-

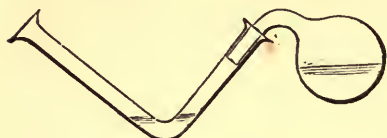
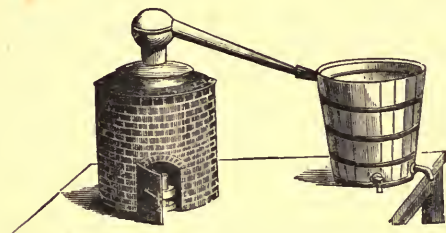
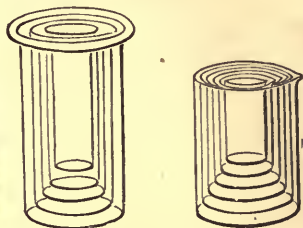


FIG. 15.

ducted on a moderate scale, and, with a very little attention and a small consumption of gas, they will readily yield a Winchester quart of distilled water per diem.

Water when absolutely pure has no taste or smell, is free from colour, except when examined in particular thicknesses, and perfectly transparent.

FIG. 16.—*Small Tin or Copper Still, with Worm Tubs, to be heated by Gas.*FIG. 17.—*Useful Vessels called Beakers, in which Solutions are prepared.*

It is invaluable as a solvent, and no laboratory is complete without a proper supply of it stored in well-stoppered bottles.

Pure water is the standard to which the specific gravities of other liquids and solids are referred.

Under the ordinary pressure of the air, it boils at 212° F. If, however, it be confined in a very strong wrought-iron vessel, such as the apparatus called a Papin's digester, the boiling-point is raised, and, as the steam does not escape, the solvent powers of the water are greatly increased. Water has in this way been raised to the temperature of 419° F., and Muschenbroek stated that he had made water hot enough in a Papin's digester to melt tin.

FIG. 18.
A Papin's Digester with Safety Valve.

The chemical composition of water may be determined analytically or synthetically. In the article on voltaic electricity it has been shown that water, when subjected in a proper manner to a current of electricity, is decomposed into oxygen and hydrogen, and if they are collected in separate tubes, the latter, eliminated at the platinode or negative platinum plate, is found to be double the volume of the oxygen set free at the zincode or positive plate. Thus the composition of water is shown to be in the proportion of two measures of hydrogen with one of oxygen. According to modern views, the atomic constitution of water is represented by the formula H_2O

$=18$, instead of, as formerly, $HO=9$.

There are many other modes of decomposing water. If steam is passed over red hot iron borings, the metal unites with the oxygen, and the hydrogen may be collected in the ordinary manner.

When the electric spark from a coil is passed through steam, the latter is decomposed into the two gases.

A small pellet of sodium, wrapped in blotting-paper and thrust under a jar full of water standing on the pneumatic trough, immediately liberates hydrogen gas, the metal taking the oxygen, and forming with the water sodium hydrate, HNaO , which is quickly dissolved. A very small piece should be used, as the decomposition occurs with explosive violence.

The common method of preparing hydrogen is by acting on zinc with dilute sulphuric acid. The probable metallic character of the hydrogen is well illustrated, because it is displaced by the zinc, sulphate of zinc is formed, and the hydrogen escapes in the gaseous state. The change which occurs is explained in the following simple equation:



Hydrogen when absolutely pure is free from colour, taste, or smell. It is the lightest of all known substances, being about fourteen times lighter than atmospheric air, and sixteen times lighter than oxygen gas.

A hundred cubic inches at 60°F . and 30 in. bar. weigh 2.14 grains; consequently the name of balloon is almost synonymous with that of hydrogen, and soap-bubbles inflated with this gas rise with great rapidity.

Hydrogen is combustible and was called by Cavendish "inflammable air." A burning taper is extinguished when introduced into this gas; hence oxygen was called a "supporter," and hydrogen a "non-supporter," of combustion. But this expression only applies to the test of a lighted taper, as a jet of oxygen may be burnt in an atmosphere of hydrogen, just as the latter will burn in one of oxygen.

This element when inhaled causes the voice to become squeaky. It is not poisonous, though, of course, it must be remembered that, if taken into the lungs, it displaces so much air, and would certainly cause insensibility if inhaled in too large a quantity.

SYNTHESIS OF THE ELEMENTS FORMING WATER.—When two volumes of hydrogen are mixed with five of atmospheric air in a long, stout glass tube provided with two platinum wires, standing over mercury, called an "eudiometer," and the electric spark passed between the platinum wires, a flash of light takes place, and expansion occurs; therefore a sufficient height of mercury must always be left in the tube: steam is formed, which condenses on the sides of the tube, and the bulk is found to be reduced to four measures, viz., the residual nitrogen left after one measure of oxygen has united with two of hydrogen.

The experiment may be varied by mixing two volumes of hydrogen with one of oxygen; the mixed gases are then allowed to pass into a very strong vessel from which the air has been carefully removed, and when full the stopcock is turned off, and the electric spark sent through the mixed gases: light is seen, but little or no sound is heard; and this experiment may be repeated over and over again, until the moisture trickles down in



FIG. 19.—A tube in which Platinum Wires are inserted, with Support to screw on the side of a Mercurial Trough.

drops of water. The instrument was first used by the celebrated Cavendish, and is always called, after his name, the Cavendish bottle.



FIG. 20.—*The Cavendish Bottle,*

Made of very thick glass, with platinum wires inserted in the stopper, which is held down by a brass framework.

A jet of hydrogen gas burnt under a gas-jar containing common air soon lines the interior with moisture.

Dry hydrogen gas passed through a heated glass bulb containing cupric oxide, CuO —the black oxide of copper—deprives the latter of oxygen. Water is formed, and the equation worked out by comparing the loss of weight of the oxide of copper with the condensed water collected affords a very instructive class experiment.

The combustion of hydrogen and oxygen for the production of the lime light has already been alluded to in the article on Light.

The combination of the two gases is induced by the presence of finely-divided platinum, which glows and becomes red hot when a jet of hydrogen is directed upon it. Little balls made of pipeclay and spongy platinum are used to effect the combination of oxygen and hydrogen. In certain cases where the analysis of a mixture of gases is made, it is usual to heat the ball before inserting it into the mixed gases, standing in a tube over mercury in the mercurial trough, of which several convenient forms are shown in the next cuts (Fig. 482).

These troughs, as their name implies, are filled with mercury instead of water, because many gases are soluble in the latter.

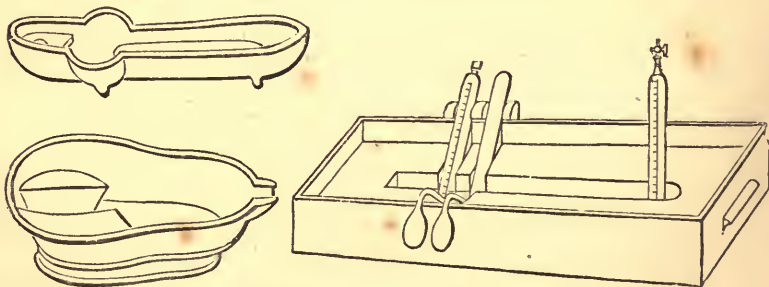
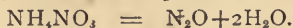


FIG. 21.—*Various forms of the Mercurial Trough.*

There is another compound of oxygen and hydrogen, called dioxide or peroxide of hydrogen, or hydric peroxide, H_2O_2 . It acts as a powerful bleaching agent, and very quickly changes into oxygen and water; hence it is called oxygenated water.

This brief description of the three permanent gases, oxygen, hydrogen, and nitrogen, will hardly be complete without alluding to the five chemical compounds of nitrogen and oxygen.

1. Nitrous oxide, or laughing gas, symbol N_2O ; made by heating dry ammonium nitrate in a retort; the salt decomposes into this gas and water.



Ammonium nitrate. Nitrous oxide and water.

2. Nitric oxide, NO ; a colourless gas, prepared by heating copper wire in dilute nitric acid. In contact with oxygen it forms red fumes soluble in water.

3. Nitric trioxide, or nitrous anhydride, N_2O_3 .

4. Nitric tetroxide, or nitric peroxide, NO_2 . Constitutes the chief portion of the red fumes produced when nitric oxide is mixed with oxygen gas.

5. Nitric anhydride, N_2O_5 , prepared by passing dry chlorine gas over chloride of silver. It is nitric acid anhydrous, or free from water, and is a white crystalline substance, called also nitric pentoxide.

Nitric acid, the monohydrate HNO_3 , of which 100 parts contain

N_2O_5	.	.	.	.	.	.	85.72
H_2O	.	.	.	.	.	.	14.28

100.00

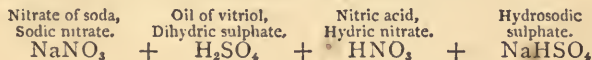
is one of the most important acids, or rather—to speak according to modern theory, “salts of hydrogen”—with which we are acquainted.

It can be made by acting on nitre with strong sulphuric acid, and is easily produced by distilling in a glass retort a mixture of the two substances.

This acid is a most powerful oxidizing agent: it will set fire to finely-powdered charcoal, or even straw, and is used in nearly every case where a metal has to be oxidized and dissolved. It was formerly called “aqua fortis,” and is used extensively in the manufacture of gun cotton and in many other chemical processes.

Nitric acid, or hydric nitrate, is prepared by heating in a retort equal weights of nitre and oil of vitriol: red fumes are produced, and a very strong acid distils over— HNO_3 —having a specific gravity of 1.517. On the large scale (when, for instance, it is required in the manufacture of gun cotton) large iron retorts lined with fire-clay are employed. Nitrate of soda is used because it is cheaper than nitre, and yields nine per cent. more acid.

The following equation explains the decomposition:



The writer has paid several visits to the admirably arranged gun cotton factories of Messrs. Thomas Prentice and Co., Stowmarket, and is enabled to vouch for the truth of the following particulars, so ably described by “Engineering,” November, 1857.

“The places at which the manufacture of gun cotton has ever been extensively carried on are but few in number. Soon after Schönbein, in 1846, made known the manner in which the material could be prepared, its manufacture was taken up to some extent at the powder-mills of Bouchet, near Paris, and in this country Messrs. Hall also commenced making it at their works at Faversham. At the latter works, however, a disastrous explosion occurred, which was attributed by the jury to the spontaneous combustion of the cotton; and after this the manufacture was discontinued, a large quantity of gun cotton which happened to be on stock at the time being buried. This was in July,

1847. In France also the manufacture was abandoned after a time, the French Commission being unable to produce a material possessing the required qualities; and in Prussia, where the manufacture of gun cotton had also been taken up by the Government, the experiments, which were carried on for eight years, were brought to an end by the blowing up of the factory. More recently, the process of manufacture advocated by Baron von Lenk was taken up strongly in Austria, where a special factory was erected at Hirtenberg; but Baron von Lenk's system did not prove perfectly successful, and in 1865 the Austrian Government gave orders that the ordnance which had been specially constructed to be used with gun cotton should be altered so that they could be used with powder, the use of gun cotton being from that date practically abandoned in the Austrian service.

"Notwithstanding these failures, however, the advocates of gun cotton—and notably Professor Abel, the director of the chemical department of our War Office—continued their researches; and, thanks to these, the manufacture of gun cotton has been very greatly improved, and is now established on a better basis than ever. At the present time gun cotton is being manufactured in this country at two places, the one being the Government powder-works at Waltham Abbey, and the other the extensive works of Messrs. Thomas Prentice and Sons, of Stowmarket, a firm who, by their extensive experiments on a manufacturing scale, have done much to bring the gun cotton manufacture to its present state. The two chief features in the processes now followed, as distinguished from those carried on by Baron von Lenk, are the pulping of the cotton after its conversion, and the admixture of this pulp, in some cases, with a certain proportion of plain cotton pulp, for the purpose of retarding the charges, or diminishing the rapidity of their combustion. The various processes followed during the manufacture of the cotton will, however, be best explained by a description of Messrs. Prentice's works at Stowmarket, which we now propose to give.

"The gun cotton factory of Messrs. Thomas Prentice and Sons is situated on the outskirts of the town of Stowmarket, by the side of a stream which furnishes a supply of water for washing purposes, and also drives a water-wheel by which the pulping machinery is worked. The factory consists of two distinct divisions, one devoted to the manufacture of mining charges, and the other to the production of cartridges for small arms, there being besides some shops common to both departments, where the conversion of the cotton and its formation into pulp are carried on.

"The raw material is received principally in the form of "waste." Formerly gun cotton was made exclusively from cotton wool; but Baron von Lenk introduced the use of cotton in the form of hanks or skeins, it being urged that these were more readily penetrated by the acids than the wool, which tended to cake into a mass when immersed. Now, however, it is found that cotton in almost any form answers equally well for the manufacture of gun cotton, the process now followed ensuring thorough conversion in all cases. The first thing done is to thoroughly cleanse the raw material. This is effected by boiling it in an alkaline solution, then drying it in a centrifugal machine, and then again boiling it in clean water. After the second boiling it is again partially dried in a centrifugal machine, and any remaining moisture is thoroughly removed, partly by exposing the cotton to the atmosphere, and partly by placing it on shelves in a drying-chamber heated artificially to about 120°. The drying of the cotton has to be very thoroughly effected, as any moisture which might

remain in it would, by combining with the acids used for conversion, generate heat and set up a destructive action. The centrifugal drying machines, which are extensively used at various stages of the manufacture, are of ordinary construction, each consisting of a cylinder with wire gauze sides, caused to revolve horizontally at the rate of from 500 to 800 revolutions per minute. A number of the machines at Stowmarket are worked from shafting driven by a horizontal engine, and others are driven each by a special engine placed close to the machine, these engines having their crank-shafts arranged vertically, and the fly-wheel of each engine being connected directly by a belt to the pulley on the spindle of the corresponding drying machine.

“The cotton, after having been thoroughly washed and dried, is weighed out in the drying-room into charges of 1 lb., each charge being placed in a wooden box in which it is passed into the converting-room. There each charge is placed separately in a bath containing the mixed acids, the mixture in which the cotton is submerged consisting of three parts, by weight, of sulphuric acid and one part of nitric acid, this mixture being allowed to cool down—a process which occupies two or three days—before the cotton is placed in it. After immersion, the charges of cotton are strained until each contains only about ten times its weight of acids, and each charge is then placed in an earthenware jar and covered down. In order to prevent any heating of the cotton from taking place, the jars containing it are arranged in a kind of shallow trough through which a current of cold water is kept constantly flowing. The building in which the conversion of the cotton is effected is ventilated by a shaft in which an artificial current is maintained; but the ventilation can scarcely be called perfect, and it is doubtful whether the fumes arising from the acids could not be more completely removed by a series of flues connected with the shaft, and arranged so as to draw off the air from the floor of the room close to the bath in which the acids are contained. This system of ventilation has been advocated by General Morin, and has, we believe, been found very effective in similar cases.

“The action which takes place when the cotton is immersed in the mixed acids is as follows: Cotton, when pure, is one form of cellulose, and is an organic compound consisting of thirty-six equivalents of carbon and thirty equivalents of hydrogen—both combustible or oxidizable elements—together with thirty equivalents of oxygen, its composition being thus expressed by the chemical formula, $C_{36}H_{30}O_{30}$. Nitric acid, on the other hand, is a powerful oxidizer, and, if added to cotton and its action assisted by heat, it will rapidly oxidize not only the hydrogen, but a portion of the carbon which the cotton contains. In the manufacture of gun cotton, however, instead of the action of the acid being assisted by heat, care is taken to abstract any heat as soon as it may arise, and the action of the acid is thus moderated, only a certain proportion of the hydrogen being oxidized, and the carbon being unaffected. The nitric acid is, as we have said, mixed with three times its own weight of sulphuric acid, and the purpose fulfilled by the latter is that of intensifying the action of the nitric acid by absorbing the water with which even the strongest nitric acid is diluted, and also the water set free by the action of the nitric acid upon the cotton. The hydrogen removed from the cotton is replaced by an equivalent quantity of nitric acid, which has lost a portion of oxygen, and has thus become peroxide of nitrogen, and it is the introduction of this component which gives the gun cotton its explosive qualities. The peroxide of nitrogen is a powerful oxidizing agent—although not so powerful a one as the

nitric acid—and it only requires the aid of heat to enable it to oxidize the carbon and the remainder of the hydrogen contained in the cotton, and convert them into gases with explosive rapidity. The heat necessary for setting up this action is supplied when the cotton is ignited, and the action is aided by the oxygen contained in the cotton itself. The proportion of the hydrogen originally oxidized by the action of the mixed acids depends upon the strength of those acids, and upon the purity of the cotton subjected to them. According to Mr. Hadow, of King's College, who has devoted much time to the investigation of the chemical changes which go on during the process of conversion, there are four distinct varieties of gun cotton, each containing a different proportion of peroxide of nitrogen. When pure cotton and the most concentrated nitric and sulphuric acids—of the specific gravities 1.5 and 1.84 respectively—are used, he states that nine equivalents of hydrogen contained in the cotton are replaced by nine equivalents of peroxide of nitrogen, its composition being thus expressed by the formula, $C_{36}H_{219}(NO_4)O_{20}$. This Mr. Hadow gives as the composition of Baron von Lenk's gun cotton; in the three other varieties he states that the numbers of equivalents of hydrogen replaced by peroxide of nitrogen are eight, seven, and six respectively. By the process of conversion the cotton is not altered in appearance, but it is materially increased in weight in the proportion of about 7 to 4.

"At Stowmarket, the cotton, after being exposed to the action of the acids for forty-eight hours in order to ensure its thorough conversion, is removed from the jars and placed in a centrifugal drying machine, which removes the greater proportion of the free acids. On its removal from the centrifugal drying machine it is plunged suddenly into a strong fall of water received by a tank, in which the gun cotton placed in the fall is allowed to remain for a short time. The object of placing the gun cotton in the fall of water, or 'drench-bath,' as it is called, is to ensure the sudden and complete submersion of the material, and thus avoid the heating and decomposition of the cotton which would take place at the surface of the water if the cotton were immersed gradually. On its removal from the drench-bath, the gun cotton is again dried in a centrifugal machine, and then placed in a bath through which a current of water constantly flows for forty-eight hours. After this it is again dried, and then placed in a second bath for a similar period, these alternate washings and dryings being repeated until the gun cotton has passed through eight baths successively, remaining forty-eight hours in each.

"After having been removed from the eighth bath and dried, the cotton is ready for pulping, a process which is in itself a washing of the most effective kind.

"The pulping machinery at Messrs. Prentice's works is driven by a water-wheel. The pulping machines, of which there are two, are similar to those employed in paper-mills.

"For making the mining charges, the pulp is first placed in a centrifugal machine, and as much water expelled as is possible by such means. When removed from the machine, the pulp is not completely dried; but the proportionate quantity of water which it contains is known, so that it can be weighed up into charges as accurately as if it were dried perfectly. The weighing of the dried pulp is effected by a number of girls, the weighing scales being situated in a light wooden building. Each charge, on being weighed, is placed in a small tin vessel, in which it is conveyed to the pressing-house, where the charges are again moistened with water. The sole object of temporarily dry-

ing the pulp is, in fact, to enable it to be accurately weighed out into charges, and after this weighing has been effected it is kept moist in all stages of its manufacture until it is subjected to the final drying process.

"The charges are first hand-pressed, and are then subjected to a more severe pressure by the aid of machinery. The hand-pressing is effected by boys, as follows: Each charge, after being moistened with water, is transferred from the tin cup containing it into a cylindrical mould or tube, the internal diameter of which is equal to the external diameter of the intended charge. At first these tubes were made solid at the lower end; but it was found that the gun cotton or pulp charge, when introduced into them, formed a kind of piston, below which the air contained in the tube became compressed, and under these circumstances it was found impossible to get the charges fairly home to the bottom of the tubes. This difficulty has been got over in a very ingenious manner. Instead of the tubes being made completely closed at the lower end, the latter is perforated, and the solid bottom on which the charge rests is formed by a piston, with which each tube is fitted. This piston is furnished with a rod, which passes up through the centre of the charge, forming a hole through the latter, which enables the charge to be ignited from end to end by the flash of the portion first lighted. In the case of charges the diameter of which exceeds about $1\frac{1}{4}$ in., the pistons of the moulds are furnished with two rods, one of these forming the central hole, and the other a hole nearer the circumference, in which the end of the igniting fuse can be placed.

"To return, however, to the process of pressing: the piston being first placed in the mould and pushed in a small distance, the charge is rammed in on the top of it, and then on the piston being forced down to the bottom of the mould by the aid of its rod, the atmospheric pressure on the top of the charge causes it to be carried down in close contact with the piston. A hollow plunger, perforated at the bottom and sides, is next placed in the mould, the end of this plunger having a hole or holes in it, through which the rod or rods of the piston can pass; and the whole is then placed under a hand-lever, by which the plunger is forced down on the charge, and the latter compressed to some extent. The charges, on being removed from the moulds above described, are next subjected to a more severe pressure by steam power. Two machines are used for this purpose, one of them, which is used for the larger charges, being a specially fitted up hydraulic press, and the other somewhat resembling a slotting machine in its general appearance. The slide of this latter machine, however, instead of carrying a cutting-tool, is fitted with three plungers, which act upon each charge successively. The charge to be pressed is placed in a cylindrical mould, carried by a horizontal circular table having an intermittent rotary motion. By one movement of this table the mould is brought under the first plunger of the slide, which partially compresses the charge, and, on the return stroke of this plunger, the further movement of the table brings the charge under the second plunger, which on making its next stroke completes the compression. A third movement of the table brings the mould under the third plunger, which on its descent forces the charge out of the mould, the latter having, by this third movement of the table, been brought over a hole through which the false bottom of the mould and the charge can pass. A fourth movement of the table brings the mould into a position where it can receive a fresh charge. The moulds and plungers are formed so as to allow of the escape of the water expressed from the charges, and the revolving table is supplied with several moulds, so that the processes of partial compression,

complete compression, and the expulsion of the charges are carried on simultaneously, there being always three charges under operation.

"For effecting the compression of the larger charges an entirely different apparatus is employed. This consists of a horizontal hydraulic cylinder, the main plunger of which is furnished with a head carrying a number of small plungers for compressing the charges, these plungers being arranged in parallel rows one above the other. Facing the plunger is the fixed head of the press upon which the pressure is received, and between this and the press cylinder is placed a block of zinc, perforated to receive the charges, and also another block, the use of which will be explained presently. Both these blocks are capable of being slid on one side, the lateral movement enabling the uncompressed charges to be placed in the zinc block. The second block, which is of iron, has, we should mention, a number of pieces of zinc let into it at the points at which the charges directly bear upon it. The method of using this apparatus is as follows: The charges to be compressed having been placed in the holes in the zinc block, the latter is brought into its proper position in front of the plungers, with the second block behind it, and secured by a simple contrivance provided for the purpose. Water is then forced into the press by pumps worked by a small steam engine close-at hand, when the plungers enter the holes containing the charges, and compress the latter to the required extent. The water pressure is next removed, and the plunger allowed to recede to a sufficient extent to leave the second block loose. This block is then run on one side, and a box furnished with as many shelves as there are rows of charges being substituted for it, the water pressure is again put on, and the plungers, advancing, force the charges out of the holes in the zinc block into the box placed to receive them. The press is, of course, furnished with a number of zinc blocks and sets of plungers, corresponding to charges of different diameters, and the arrangement is found to be a very efficient one.

"The next process undergone by the charges after pressing is that of being covered with a peculiar kind of paper termed 'artificial vellum.' This artificial vellum, which is manufactured by Messrs. Prentice on their own works, is made by laying sheets of blotting-paper for a few seconds on the surface of strong sulphuric acid contained in a suitable bath. The paper, after being subjected to the action of the acid, is immediately washed by plunging into troughs containing water, and on its removal from these troughs it is ready for use. The process of manufacturing this material is a very interesting one to witness, the artificial vellum being a tough semi-transparent substance, so entirely different to the blotting-paper from which it is produced, that it is almost difficult to believe that the transformation could be effected by such simple means. The artificial vellum is cut into strips, rolled around the charges, and secured by paste, the operation of covering the charges being performed by girls.

"After being covered the charges are ready for the final process of drying; and this drying is effected by the aid of steam, the drying-stove being situated at some little distance from the sheds in which the other processes are carried on. The stove consists of a small brick erection enclosing the steam-pipes, the top of the brickwork being fitted with a number of vessels in which the charges to be dried are placed. The vessels are separated from each other by division walls carried up between them, so that, in the event of the contents of one vessel becoming ignited, the flame will not be communicated to the

other vessels, and they are protected from the weather by light hoods placed over them. The charges are dried at a temperature of about 140° , and efficient means are provided for ensuring that the temperature shall never rise above a perfectly safe limit.

"We have seen that, in the case of the mining charges, the pulp is, during the process of manufacture, subjected to very severe compression, and by this means a very great quantity of explosive matter is obtained in a small bulk. A mining charge, in fact, manufactured by the processes now followed at Stowmarket possesses an amount of explosive power six times as great as that of a similar bulk of gunpowder; and this concentration—if we may term it so—of the explosive material is in many instances of great value. Thus, when hard materials have to be blasted by charges contained in holes bored only to a moderate depth, a gun cotton charge, occupying only one-sixth the length of hole that would be taken up by a gunpowder charge of equal power, allows of a greater length of tamping being employed, and also concentrates the explosive action at greater distance from the working face. There is also now abundant evidence that gun cotton is in other respects a more effective explosive for mining and quarrying purposes than gunpowder. Thus, in breaking up large boulders by means of a charge inserted in a vertical hole bored from the top down to near the centre of the boulder, if a gunpowder charge is employed, its tendency is, if the block is of large size, to blow out a conical mass from the upper part of the boulder, the apex of this inverted cone being situated at the point where the charge is placed. With gun cotton, however, the case is different, it being found that it exerts a powerful splitting action below as well as above the point where the charge was situated. This effect appears to be due to the extremely rapid action of the gun cotton; but, whatever may be the cause, it is an effect which is found to occur in practice, and one which makes gun cotton particularly valuable for quarrying purposes."

There are some very remarkable circumstances connected with the ignition of gun cotton which show that almost any rate of combustion may be obtained by using a variety of heat-giving agents.

Thus, if a length of gun cotton yarn is fired with the incandescent charcoal or glowing spark at the end of a piece of string after the flame is blown out, it causes the cotton to burn slowly like a squib. If the flame of the burning string be used, or any other flame, the gun cotton puffs off with the usual rapidity of combustion.

A still more rapid combustion is secured by exploding gun cotton with fulminating mercury, when the destructive and rending power is tremendous. The writer witnessed some experiments kindly conducted by Messrs. Prentice at Stowmarket. Loose gun cotton may be laid by the side of a wall or stout wooden palisade, and if fired in the ordinary way with flame, little or no effect would be produced; but when the fire is communicated to the gun cotton by the concussion or combustion of fulminating mercury, the same kind of almost electric rapidity of combustion is conferred on the gun cotton, which explodes with a loud noise, and will then blow down the wall or wooden fencing with comparatively moderate charges.

There are, therefore, three distinct rates of combustion belonging to gun cotton, which are determined by the nature of the fire used:

1. A spark of incandescent charcoal causes it to burn slowly, like a pyrotechnic mixture.
2. With flame it puffs off rapidly.

3. By the fire and percussive power of fulminating mercury gun cotton explodes with the fearful violence belonging to trinitro-glycerine, which is supposed to have at least ten times more explosive force than gunpowder, and is so dangerous that its use in England is virtually arrested from the circumstance that no railway or ship will knowingly carry this terrible oil, which is prepared from glycerine by the action of concentrated nitric acid.

Glycerine— $C_3H_8O_3$ —acted upon by strong nitric acid is converted into trinitro-glycerine, in which three atoms of typical hydrogen are replaced by three of nitric peroxide, $C_3H_5, 3NO_2, O_3$, affording another remarkable instance of the fact that all the most dangerous explosive bodies contain nitrogen.

"The Times" of 28th January, 1869, gives the following graphic account of the effect of various charges of gun cotton, fired with the detonating fuse, by Messrs. Thomas Prentice and Co., at Stowmarket. After many details of the manufacture of the gun cotton, the article concludes as follows:

"On quitting the practice-ground, the party set off to walk far afield, for though small charges of gun cotton may be fired close to a village, it is otherwise with quantities large enough to blow down palisades or break up trunks of trees. As the first experiment, a disc of gun cotton, weighing about 1 lb. 1 oz., was placed on the stump of a tree lately cut down, and ignited by an ordinary piece of miner's fuse. At the instant of ignition it was enveloped in flame, and sailed merrily about for the two or three seconds required for its combustion. The gas produced lifted it up and caused it to move. Then about half the quantity was placed on the same spot and ignited by a small detonating tube. A sharp, sudden report was heard, and the stump was found on inspection to be partly penetrated just where the charge had lain, while the twigs of the hedge close by suffered severely. On seeking for a new illustration a large tree-root was seen, which had been torn out of the ground, and offered among its gnarled and bossy structure a favourable position to deposit a charge. One of the discs, about 1 lb. 1 oz., was accordingly placed at the mouth of a small cave that seemed inviting. The gun cotton was not buried in the mass, but only laid, as it were, on a shelf perfectly open to the air. The gentlemen present retired to what they considered a safe distance, about fifty yards. There seemed to be some doubt about the effect. Is it possible that so small a quantity of gun cotton could rend such a mass, even if buried in it? Surely not when it is only laid on the floor of an opening. The moment of explosion is anxiously awaited. A man lights the fuse and runs for his life. There is a little smoke. Is the cotton burning as the first sample did? Wait a little yet. The tube has not given its sharp, cracking sound. One moment more, and then a report and a rush through the air of masses of wood—overhead, right, left, in front, everywhere! Soldiers who have known what it is to be under shell fire ducked to dodge a big lump of knotted wood that sprang sixty-four yards from its parent root, just clearing the heads of the party. It was only for a moment, and then everybody ran to see what had been done. The whole great root had simply been shattered to pieces, and grinning countrymen exclaimed, 'We hope you'll sarve a few more on 'em so for us.' A little awed by what they had seen, the visitors toiled and tumbled over a heavy ploughed field to see a row of palisades composed of three trunks, some of them 18 in. in diameter, and all sunk 4 ft. into the ground. Since the last explosion everybody had been a little more careful about lighted cigars, forgetting that a cigar or even a match would ignite the gun cotton in quite another fashion. A long tree-trunk lay touching the foot of the palisade,

and upon this 5 lb. of gun cotton was laid. Wires communicating with a magnetic apparatus were affixed to a detonating tube, which was placed in contact with one of the discs of gun cotton. 'But surely they won't all detonate, for only their circumferences touch at one point?' Wait and see; back over the heavy furrows a good 150 yards, no one being anxious to stand too near this time. The time of suspense was short, and then the explosion was heard. One mass of wood only was seen to plunge away from the palisade; it was the recumbent trunk upon which the cotton had been laid. The palisades themselves were standing, though a good deal damaged—no practicable breach. But there still remained a long space of palisading yet untouched, and here, instead of 5 lbs., 15 were laid, partly built on each other. The excitement began to increase. It was the old story of the targets and the guns, and now several people might have been found to back the palisades. Fuse and wires were placed. Everybody retired to a safe distance. Man's nervous organization is curiously elaborated, and it is not to be wondered at that there were several exclamations of, 'Please tell us just when you are going to fire.' Some persons put two good banks between them and the expected explosion, others sought the grateful shelter of a ditch. All were trying to combine the maximum of view with the minimum of danger. At last came the sharp, powerful crash, so unlike the dull roar of gunpowder, and this time there could be no mistake about the effect. Huge logs were seen performing summer-saults at greater or less distances from the explosion, while smaller pieces, some about a couple of feet square, bounded like rabbits over the field. Men of science, officers, country gentlemen, and bumpkins were soon spread over the ploughed field, each striving to be first in at the death. On reaching the target the effect appeared to have been tremendous. In some places a tree-trunk had been cut in half, almost as with a rough saw, only not so straight; in others the solid wood was mangled, so that it could be pulled to pieces by the hand. Three logs had been cut down or smashed, and it was clear that no stockade or New Zealand pah could withstand such deadly effects for an instant. Exclamations of astonishment showed the mental impressions produced. '*Superbe!*' '*Prodigious!*' '*Extraordinary!*' '*Magnificent!*' '*Mais c'est une maniere de faire les allumettes!*' And all this had been done by only 15 lbs. of the cotton. Three times the quantity made up into a cylinder could be carried with ease by a man at a run, who might also drag the ends of the two wires as they unwound from a reel kept in a position of safety. Is there no hint here for the colonists? No fire need be seen, for there is no match to light. Surely plenty of volunteers could be found to perform such work at night, and so restore the superiority of civilized man over savages. It had been contemplated to tie a ring of gun cotton round a living tree, and see if it could not be cut down; but there was not time enough. The experiments were over for the day, and the visitors returned to London, satisfied that they had seen a most marvellous phenomenon, and one which is only a first step to a whole array of novelties in the arts of war and of peace."

When the tremendous powers of modern artillery with improved gunpowder, and all the terrible refinements in the management of gun cotton, are considered, it is amusing to compare the latter with the bows and arrows used only three centuries and a half ago.

Extract from the "Edinburgh Courant."—"I have seen a man who conversed with a man who fought at Flodden Field, may be said by a venerable octogenarian gentleman, to whom we are indebted for the following most inte-

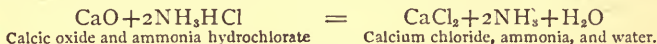
resting memorandum :—The writer of this, when an infant, saw Peter Garden, who died at the age of 126. When twelve years old, on a journey to London about the year 1670, in the capacity of page in the family of Garden of Troup, he became acquainted with the venerable Henry Jenkins, and heard him give evidence in a court of justice at York, that he ‘perfectly remembered being employed, when a boy, in carrying arrows up the hill at the battle of Flodden.’”

It was fought in	A.D.
Add Henry Jenkins's age	1513
Less:	169
... ..	11
... ..	158
Peter Garden	126
Less his age when at York	12
... ..	114
The writer of this in 1865 aged	80
... ..	1865

NITROGEN AND HYDROGEN, AMMONIA, $\text{H}_3\text{N}=17$.

Many thousand years ago the Egyptians worshipped a god “Ammon,” and it is said that as this compound was first obtained from a substance found near a temple devoted to the worship of this divinity, situated in the Oasis of Ammonium (*Sirwah*), in the Libyan Desert, celebrated for its oracle and visited by Alexander the Great,—as the compound was first discovered near this temple, it was called Sal Ammoniac.

Quicklime and sal ammoniac, or ammonia hydrochlorate, NH_3HCl , when mixed and gently heated, give calcium chloride, ammonia, and water.



Ammonia is also given off when animal matter is heated, such as the horns of animals, and hence it was called “hartshorn.” The first ammonia was doubtless obtained by the Arabs near the temple of Jupiter Ammon, by heating camels’ dung.

Coal is the great source of ammonia, and this is not surprising when it is understood that it contains 2 per cent. of nitrogen.

Guano and other manures are applied to the land because they contain free ammonia, or other nitrogenous matter, ready to change into ammonia and to be assimilated by plants.

When sal ammoniac and quicklime are heated in a flask provided with a cork and tube, the gas may be collected over mercury. It is colourless, but possesses a very strong odour, affecting greatly the olfactory nerves, and causing a flow of water from the eyes, and hence is used as a refreshing stimulant, and is slowly evolved from mixtures called “smelling salts.” Being lighter than air, it may be collected by holding a clean dry bottle over the mouth of a flask containing the mixture of lime and ammoniacal salt; it is better, however, to pass the gas first through a bottle containing quicklime, in order to remove the moisture. Calcic chloride must not be used, as it absorbs ammonia and forms a definite compound with that body.

The specific gravity of ammoniacal gas is 0.590, air being 1.000; and therefore it fills an inverted bottle by displacement.

Ammonia cannot be collected over water, as it is so very soluble in that liquid. At the freezing-point water takes up 1.050 times its volume; at 59°, 727 times its volume; at 78°, 586 times its volume.

By conducting the ammoniacal gas into a series of Wolfe's bottles provided with safety tubes, the ordinary solution of ammonia may be prepared.

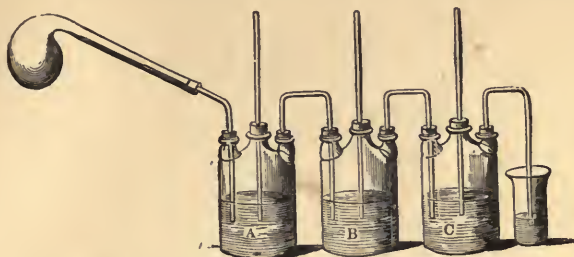


FIG. 22.—Retort fitted to a series of Wolfe's Bottles,
All provided with safety tubes.

Whilst the ammonia is being dissolved the water becomes very hot, and if kept at 60° by the application of a current of cold water, it will dissolve one-third of its weight of the gas, and, becoming specifically lighter, is then found to have increased in bulk by one-half. The specific gravity of the strongest solution of ammonia at 57° is 0.884, water being 1.000.

Various safety tubes are made when gases are passed into water or other solutions: one of the most elegant is that shown in the annexed cut. The object of a safety tube is to prevent the flask being crushed or the liquid returning into the materials by any sudden condensation and formation of a vacuum.

Blotting-paper coloured yellow with turmeric, called turmeric-paper, is instantly changed to a reddish brown when brought in contact with ammonia. Other alkalis affect the turmeric in the same manner; but the effect of ammonia is soon distinguished from others, because, on the application of heat to the paper, the ammonia is driven off, and the yellow colour of the turmeric is restored.

At a pressure of seven atmospheres, at 60° , ammonia (the gas) condenses into a liquid, and is used in M. Carré's freezing apparatus, which was exhibited on a grand scale at the Great French Exhibition of 1867.

Ammonia is formed by the union of three volumes of hydrogen with one of nitrogen, and its symbol is therefore H_3N .

There are two other compounds of nitrogen and hydrogen, which have not yet been obtained in an isolated form, viz.,

Amidogen, $H_2N = 16$.
Ammonium, $H_4N = 18$.

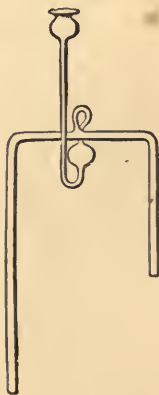


FIG. 23.
A Safety Tube, for
Experiments with
Gases, &c.

THE HALOGENS

(From $\alpha\lambda\sigma$, sea-salt),

CHLORINE, IODINE, BROMINE, AND FLUORINE.

A Group of Monads.

CHLORINE.

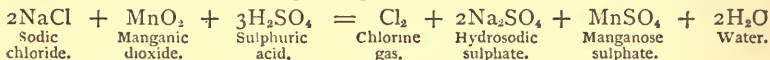
Symbol, Cl. Atomic weight, 35.5.

The fact that sea-salt is the chief source of Chlorine is sufficient to demonstrate its plentifulness; and its presence in soils, plants, animals, natural waters, sea-water, sea-salt, and rock-salt, all confirm the statement.

This gas, discovered by Scheele in the year 1774, is called chlorine from the Greek $\chi\lambda\omega\rho\sigma$, green, in allusion to its peculiar yellowish-green colour.

The gas is easily procured by boiling hydrochloric acid with black oxide of manganese.

To obtain chlorine from salt, the latter is first mixed with the black oxide of manganese, and the sulphuric acid, diluted with water, is then added. The proportions are 4 parts by weight of salt, 3 of black oxide of manganese, 10½ sulphuric acid previously diluted with 7 of water. When these materials are carefully heated, the following change occurs:



The gas must be carefully collected, and even the first portions mixed with air should be passed into a spare jar. If by accident the chlorine is inhaled, it causes the most violent irritation of the air-passages, and this occurs frequently when the chlorine is largely diluted with air, so that no inexperienced manipulators (boys, for instance) should be allowed to make it without a proper person to assist them. When very largely diluted with air, the odour is not disagreeable, reminding one of the smell of the sea.

Chlorine is much heavier than air; 100 cubic inches weigh 77.5 grains at 60° F., 30 in. bar. The density of this gas being 2½ times greater than air, it may be collected by displacement like carbonic acid, and, as recommended in the collection of ammonia, it is better to deprive the chlorine of moisture by passing it through a Wolfe's bottle containing a small quantity of sulphuric acid or calcic chloride.

The operator who employs this method must be very careful, and probably, to prevent accident, it is better to put warm water in the pneumatic trough, and use that in preference to the displacement method, because water at 60° dissolves quite twice its volume of chlorine, and thus all danger may be avoided by being able to watch the collection of the gas.

A lighted taper placed in chlorine gas burns with a reddish flame, an abundance of smoke being produced, in consequence of the chlorine combining with the hydrogen, whilst the carbon is deposited in part.

The great affinity (or desire to combine) between hydrogen and chlorine is shown in a very striking manner when equal volumes of the two gases are placed in a thin bulb of glass. If this bulb be held in a red light produced by passing the electric light through red glass, no change occurs; but directly the violet rays, obtained in excess by passing the light through violet glass, are allowed to fall upon the mixed gases, they explode, and hydric chloride is produced.

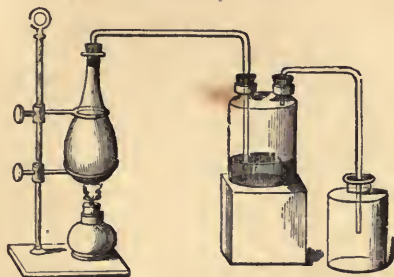


FIG. 24.—*Preparation and collection of Chlorine by displacement.*

If the eyes are protected by a screen of wire gauze held before the bulb, no harm can occur from the bits of very thin glass.

Hydrogen is now regarded as a metal, and analogy indicates more "presumptive evidence" that this is the case, because other metals, though they do not explode with chlorine, are quite ready to burn, and do, in fact, take fire when sprinkled in fine powder into this gas, viz., finely-powdered antimony, copper, and gold in leaf, also arsenic, likewise phosphorus.

Chlorine has very powerful bleaching properties, and is in effect an oxidizing agent. It is always ready to unite with the hydrogen of water: the latter undergoing decomposition, oxygen is eliminated; and this in the nascent, condensed state, like ozone, destroys many vegetable colours.

A little solution of sulphate of indigo is rapidly bleached when shaken with some chlorine gas.

Chlorine gas unites with oxygen in various proportion,

1. Hypochlorous anhydride, $\text{Cl}_2\text{O}=87$.

2. Chlorous anhydride, $\text{Cl}_2\text{O}_3=119$.

3. Chloric peroxide, $\text{ClO}_2=67\cdot5$.

From the two first, by union with hydrogen, are the following:

1. Producing hypochlorous acid, $\text{HClO}=52\cdot5$.

2. " chlorous acid, $\text{HClO}_2=68\cdot5$.

3. " no known acid yet obtained.

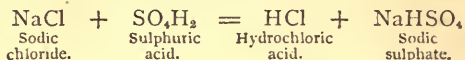
4. (*No corresponding oxide of chlorine yet discovered*); producing chloric acid, $\text{HClO}_3=84\cdot5$.

5. (*No corresponding oxide of chlorine yet discovered*); producing perchloric acid, $\text{HClO}_4=100\cdot5$.

THE COMPOUNDS OF CHLORINE WITH HYDROGEN.

HYDRIC CHLORIDE (Spirit of Salt), HYDROCHLORIC ACID (Muriatic Acid), $\text{HCl}=36\cdot5$.—As already stated, equal volumes of chlorine and hy-

drogen exposed to the strong light of day or violet light, combine and form the same volume of hydric chloride. This important acid is prepared by distilling metallic chlorides with sulphuric acid, and, of course, the cheapest is sodic chloride, or common salt. The following equation explains the decomposition:



The same apparatus (Fig. 22, p. 41) may be used for dissolving hydrochloric acid in water, and therefore, being so soluble in the latter, it must be collected in the mercurial trough, or by displacement in dry bottles. A hundred cubic inches at 60° F., 30 in. bar., weigh 39·64 grains.

Under a pressure of forty atmospheres it is condensed into a fluid.

The ordinary solution in water as sold in the shops is an almost colourless fluid. The strongest commercial acid contains 4·2 per cent. of real acid, and has a specific gravity of 1·210. It is impure, and contains iron, arsenic, &c.

The gas extinguishes flame, and is not combustible. The solution of the acid gas in water is most useful for analytical and other purposes in the laboratory.

The compound of chlorine with nitrogen (HCl_2N , Cl_3N), called chloride of nitrogen, is most dangerous and explosive, and should never be prepared, as it is running a useless risk, the properties of the compound being already known.

Chlorine also unites with carbon, forming at least four distinct compounds.

IODINE.

Symbol, I. Atomic weight, 127.

Discovered originally by Courtois in the waste liquors obtained in the manufacture of carbonate of soda (sodic carbonate) from the lixiviation of the ashes of seaweed, Iodine is prepared from kelp, the fused ashes of burnt seaweed, and is largely manufactured on the western shores of Scotland and Ireland. The kelp is first broken up into small pieces, and digested with water; the latter dissolves about one-half, consisting of the chlorides and carbonate of soda, also chloride of potassium and iodide of sodium (sodic iodide) and other salts; these are in great measure deposited by evaporation and crystallization, and as the iodide of sodium is the least soluble, it remains behind in what is called the "mother liquor" or "bittern;" this, placed in a proper vessel and distilled with black oxide of manganese and sulphuric acid, in the same manner as already described in the preparation of chlorine from salt, oxide of manganese, and sulphuric acid (p. 42), yields the violet vapours of iodine,—so called from the Greek $\omega\delta\eta\varsigma$, purple.

An experiment on the small scale may be made by gently heating a little solution of iodide of potassium in a flask with oxide of manganese and sulphuric acid, when the iodine is rendered apparent by the colour it imparts to the air in the upper part of the flask. (Fig. 25.)

Iodine condenses into a dark grey solid, having a brilliant metallic lustre. It is extremely volatile, rising in vapour below the freezing point of water: it

freezes at 225° , and boils at 347° , emitting an odour very much like that of chlorine. It has feeble bleaching powers, and is slightly soluble in water.

It attacks certain metals, forming iodides with them, and it may be again separated by chlorine. Starch is the most delicate test for iodine, with which it forms a purple compound. The colour, obtained by pouring a little tincture of iodine into a flask containing some starch, disappears when the fluid is boiled, but returns again after it has cooled. Iron or zinc filings placed with iodine and water in a beaker glass are soon converted into iodides and dissolved in the water.

Phosphorus takes fire when brought into contact with iodine. Iodine is used extensively in medicine; but another and most important application of this element deserves special notice here in connection with the art of photography, and the Author is indebted to his friend, Mr. John Spiller, Hon. Sec. of the Photographic Society, for the following *résumé*.

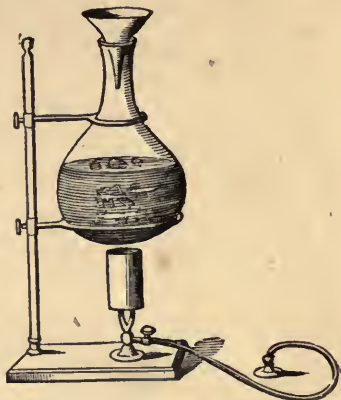


FIG. 25.—Production of Iodine Vapour from Potassium Iodide.

THE ART OF PHOTOGRAPHY.

The invention of Photography as a practical art may be said to date from the year 1839, when M. Daguerre, in France, and the Hon. H. Fox Talbot, in this country, described almost simultaneously the respective processes which have since been identified with their names. The daguerreotype is commonly known as the process of obtaining a photographic impression upon a highly polished silver, or electro-silver, plate, the surface of which is rendered sensitive to light, or rather to the *actinic* principle of the sun's rays, either by the action of iodine alone or a mixture of bromine and iodine. Exposing the plate so prepared to light in a properly constructed camera obscura, and afterwards rendering manifest the graduated change induced upon the coated surface of the metal by placing it under the influence of mercury vapour, which then is found to attach itself most abundantly to those parts of the image where the light has acted with the greatest intensity, thereby forming a lustrous amalgam, which adheres firmly to the plate, even when the excess of unaltered iodide of silver is removed by washing with an aqueous solution of hyposulphate of soda or other chemical solvent. The daguerreotype image is sharp and delicate, and when coloured of a warmer tone by the final application of a gold salt (using by preference the *sal d'or* of MM. Fordos and Gélis), is admirably adapted to portraiture, to the delineation of microscopical subjects, and to the recording of celestial phenomena. Its chief drawback lies in the circumstance that the silver plates are liable to become tarnished in the course of time, however carefully mounted, and, further, that these photographs are somewhat difficult of multiplication.

Mr. Talbot's process, originally known as the "calotype," but afterwards named in honour of the inventor the "Talbotype," depends likewise upon the

sensitiveness to light of the iodide of silver; but the mode of producing the argentic compound, the medium upon which it is spread, and the process of developing the *latent image*, are so totally different, that it must be regarded as a specifically distinct application of chemical science.

Plain or waxed paper is immersed in a solution of iodide of potassium, and after a few minutes removed, drained, and hung up to dry. In this condition it is stored ready for use, and may be *sensitized* by being floated on a solution of nitrate of silver of a sufficient degree of concentration to leave an excess of the latter in the pores of the paper, and necessarily in immediate contact with the precipitated particles of iodide of silver. Whilst still slightly moist, the sheets of paper are enclosed in suitable dark slides, and are ready for exposure in the camera; or this operation may be deferred for any time short of twenty-four hours. The pictures are developed by dim candlelight, or in a room from which all but the yellow non-actinic rays of daylight are cut off by the use of deep orange panes of glass or curtains of yellow calico, by the following process: Gallic acid, in aqueous or weak acetic solution, is first washed over the paper, and, as soon as the photographic image has become distinctly visible, a mixture of gallic acid and aceto-nitrate of silver is applied, which gradually augments the intensity of the developed image until the high lights in the original are represented in the picture by intense blacks, and all the gradations of shading appear to be truthfully rendered, but inversely, in the *negative*. Washed and fixed by the application of hyposulphate of soda, as suggested by Sir John Herschel, the operator is in the possession of a permanent record, from which an innumerable succession of *positive* pictures, true to nature, may be obtained by sun-printing upon paper prepared with the chloride of silver, as afterwards explained. The peculiar advantages of the talbotype were the facilities it afforded to the landscape photographer, who, preparing his paper early in the morning, could always rely upon obtaining a number of good negatives by development in the evening. The comparatively long period required for exposure in the camera (from five to ten minutes) necessarily limited the use of this process to objects of still life; but great results, even in portraiture, were obtained by those who perseveringly devoted themselves to the surmounting of a number of mechanical difficulties connected with the selection of the paper and its mode of preparation. An early improvement consisted in the use of the argento-iodide of potassium, as prepared by dissolving iodide of silver in a tolerably concentrated solution of iodide of potassium. This double salt applied to the paper as a single wash furnished the means of preparing a superior description of iodized paper of a fine primrose tint, by simple immersion, partial drying, and afterwards floating on water to effect the removal of the alkaline iodide. With this material a very weak gallo-nitrate of silver was commonly employed for sensitizing, and the papers after exposure showed a faint image prior to being subjected to the development process already described.

The collodion process, invented by Mr. Scott Archer in 1851, has almost entirely superseded the two earlier systems of photography. It cannot be said, however, to be altogether independent of Mr. Fox Talbot's original principle, for the same condition of iodide of silver is employed, and very similar methods of development and fixing are resorted to. The pictures are obtained upon glass plates coated with a film of exquisitely sensitive material, consisting of particles of newly precipitated iodide of silver, supported in a transparent network of pyroxyline or gun cotton, as left by the evaporation of

the ethereal mucilaginous material now so well known under the name of *collodion*. For the production of this film of iodide of silver, a suitable quantity of iodide of potassium, or of cadmium, is dissolved in alcohol and mixed with the plain collodion, and the necessary silver is supplied by immersion of the coated glass plate in an upright "dipping bath" of nitrate of silver. Removed after a few minutes' contact, the plate is ready for the camera, and should be exposed without delay. Upon being taken back to the operating-room to undergo the process of development, there is absolutely nothing in the shape of a picture visible upon the plate until the developer is applied, which solution may either consist of the green sulphate of iron, or a dilute solution of pyrogalllic acid in water rendered slightly acid with acetic or other organic acid. The operation of these chemical agents is powerfully reducing, and they consequently effect the reduction of the soluble argentic salt remaining in excess upon the plate, the particles of finely-divided metallic silver so precipitated being deposited by preference upon the nuclei of altered molecules of iodide of silver, with gradations varying according to the intensity of the light which has acted on those parts. Thus, then, is obtained, with proper exposure in the camera, an exquisitely delicate negative image in pure silver upon a stratum of collodion, containing still some yellow iodide of silver in admixture. The latter is removed by washing with a solution of hyposulphate as before, and the plate is well rinsed, dried, and protected with a coating of varnish.

From the negatives, whether obtained by the collodion or the calotype process, a great number of positive impressions may be prepared by following the manipulation of what is called the *printing process*. For this purpose it is usual to employ the chloride of silver spread upon paper with an addition of egg albumen and an excess of the nitrate of silver.

The ordinary mode of proceeding consists in applying to one side of a sheet of paper a mixture of well-beaten white of egg, salt, and a proportion of water varied according to the degree of lustre desired in the finished photographs: for general purposes the following instructions may be followed:

White of egg	.	.	.	.	.	.	10 oz.
Water	.	.	.	.	.	.	5 "
Common salt	.	.	.	.	.	.	$\frac{1}{2}$ "

For landscapes and portraits of large size the quantity of albumen may be advantageously diminished, whilst, on the other hand, it may often be necessary to limit the addition of water when the maximum degree of sensitiveness and delicate rendering of detail in *cartes de visite* or other small prints are the objects sought. The mixture of materials above prescribed is poured, without agitation, into a flat dish, and one side of the paper is then slowly laid down upon the surface of the salted albumen. After two minutes' contact the sheet is again carefully removed, and hung up to drain and dry. In this state the salted albumenized paper may be preserved for a great length of time, and when required for use, it is necessary to float it for two or three minutes upon a 50-grain solution of nitrate of silver.

In order to perform this and most of the subsequent operations with success, it is customary to screen the light entering the windows of the photographic room by interposing one or more folds of yellow calico; for, when dry, the sensitized paper will become bronzed or blackened by a comparatively short exposure to the sun. In this sensitized condition, the prepared side of

the paper is brought into contact with the collodion face of the negative, and the two held together under slight pressure in a properly constructed printing-frame, in which it is now ready to be exposed to the light, observing only the precaution of not subjecting the varnished negative to the direct and hot rays of a midsummer sun. Examined by lifting one-half of the hinged back and the paper from the face of the negative, the progress of the printing operation may be watched, and interrupted at the proper stage—when the intensity of the print has become slightly deeper than the finished result is required to be. At the end of a day's work it is customary to wash, tone, and fix the prints, which is carried out by immersing in water, for ten or twenty minutes, the prints so obtained, pouring off the excess of nitrate of silver solution, and leaving them in a fresh supply of water, ready for the toning operation.

Take	Chloride of gold	4 grains
	Bicarbonate of soda	} 15 "
	Acetate or phosphate of soda	
	Water	1 pint

The washed prints are separately transferred to this solution, and immersed for a period of time (two or three minutes) sufficient to effect a change of colour from foxy red to bluish purple. When this stage is reached they must be quickly removed into a capacious dish of water, and, thus toned, are ready for the fixing bath, composed of

Hyposulphite of soda	4 oz.
Water	1 pint

They will need to be very thoroughly washed by immersion either in a running stream of water, or in dishes the contents of which are frequently changed. The prints when dry are trimmed and mounted.

Other systems of photographic printing are occasionally adopted; thus, instead of employing the albumenized paper just now described, the use of plain salted paper for a small surface is resorted to, following a similar treatment in the printing, toning, and fixing operations; or, lastly, a somewhat novel mode of reproduction consists in making use of the very beautiful invention of Mr. G. Wharton Simpson, known as the *collodio-chloride* process. For this purpose a collodion, specially prepared from chloride of strontium and nitrate of silver in a vehicle containing the constituents of plain collodion, is found to possess the singular property of holding in suspension for a great length of time the impalpable particles of chloride of silver produced by the admixture of the two above-mentioned salts. Preserved always in the dark, this collodio-chloride preparation is poured over a plate of white enamelled glass, the coated side of which, when dry, is placed in contact with the negative to be printed, and the delicate image resulting from its exposure to light is fixed in the same manner as an ordinary collodion picture.

Wonderfully fine results are obtained also by certain systems of camera printing, or inversion of the process by which the glass negative is originally obtained. These developed pictures, toned with gold and mounted with an opaque white gelatine backing, have attracted much attention under the name of "Eburneum" photographs. If otherwise treated as transparencies, they become very suitable for exhibition in the magic lantern, or, with ground glass behind, they have been made to do duty in the stereoscope.

The so-called "carbon photographs" are prints obtained upon a tissue of

gelatine and bichromate of potash, with which has been incorporated carbon itself in the form of lampblack or Indian ink, or any equivalent dark-coloured pigment. By exposure to light the gelatine becomes hardened and insoluble, so that in the high lights of the picture much of the colouring matter is locked in the material, whilst in the protected portions of the print all the gelatine and pigment washes away, leaving the white paper or other basis of the transfer freely visible, and the half-tones are properly represented by graduated layers of altered gelatine, the varying thicknesses of which are dependent upon the intensity of the light's action.

The latest modification of the principle involved in the carbon printing process of Mr. Swan is one by which the final results are obtained by mechanical printing, from a metal block which bears the impress of the delicate gelatine relief resulting from a mode of working similar to that just now described. This metallic plate is charged with a liberal supply of warm ink (composed of gelatine and suitable pigments), then covered with white paper, and pressure is immediately applied for the purpose of driving out all the extraneous ink. When cold, the print is lifted from the metal block, and fixed by immersion in alum-water, which renders the gelatine completely insoluble. This mode of proceeding is the invention of Mr. Walter B. Woodbury, and the resulting proofs are commonly known as "Woodburytypes." Their exquisite delicacy brings them into favourable comparison with the best results of the silver printing process; and it will be remarked that when the gelatine matrix is once procured, the subsequent operations are entirely independent of the action of light.

Iodine, like chlorine, unites with hydrogen, forming an acid called hydriodic acid or hydric iodide. The symbol of this acid is HI, and its atomic weight 128.

Hydriodic acid is a gas which fumes strongly when brought in contact with the air: it is very heavy, the specific gravity being 4.443. Like hydrochloric acid, it may be collected by displacement, and is composed of one volume of hydrogen and one of iodine, forming two volumes of hydriodic acid.

There are some oxides of iodine and two important acids:

Iodic acid or hydric iodate (symbol, HIO_3);

Hydric periodate or periodic acid (symbol, HIO_4);

Iodic pentoxide (symbol, I_2O_5);

and iodine appears to have a stronger affinity or attractive power for oxygen than either chlorine or bromine. It unites also with chlorine and bromine, and forms an explosive compound with nitrogen, NI_3 , in which an analogy in molecular composition to ammonia is at once apparent, three atoms of hydrogen being replaced by three of iodine.

BROMINE.

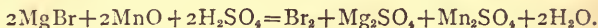
Symbol, Br. Atomic weight, 80.

This element (perhaps a *quasi* element, for there is every probability that it will one day be resolved into another and more elementary condition) bears a close resemblance to chlorine, and has many properties in common with that element. It was discovered by Balard in 1826, in the same liquid, "bittern,"

which furnished iodine, with this exception, that Balard's "bittern" came from the mother liquor of the salt marshes of Montpellier.

Near Kreuzénach, at a place called Theodorshall, is a salt-spring, and from this water a considerable quantity of bromine is obtained.

The iodine, as in the instance of the mother liquor of varec, is first got rid of by passing chlorine gas into the liquor until a sample gives no precipitate with chlorine; the residual fluid is then mixed with black oxide of manganese and sulphuric acid, and distilled, and the same kind of change that occurs in the preparation of chlorine or elimination of iodine takes place in this case also, and bromine is obtained.



Bromine is extremely volatile: a few drops thrown into a bent tube soon fill it with red vapour. It is a non-conductor of electricity. At -22°C . it assumes the solid state, and is then of a dark greyish lead-colour, with a partial metallic lustre.

The smell of bromine is, like chlorine, very suggestive of the odour of sea air. In a concentrated state the vapour is irritating, and it was from this circumstance that the element was named *βρωμος*, a stink.

The specific gravity of bromine in the state of vapour is 5.540; in its ordinary liquid state the specific gravity is 3.187 at a temperature of 32°F . Bromine, like chlorine, is a powerful bleaching agent: it is very corrosive, attacking cork and wood, which are changed yellow and become disintegrated and rotten. A very little drop will kill a small animal. The same atomic relation to hydrogen observed with chlorine and iodine occurs with this element.

Hydrobromic acid or hydric bromide (symbol, HBr ; atomic weight, 81) consists of equal measures of hydrogen and bromine vapours united, but retaining the same volume. The compounds of oxygen and bromine, although numerically less, are very similar to those of chlorine and oxygen.

Hypobromous acid, HBrO ;

Bromic acid or hydric bromate, HBrO_3 .

Perbromic acid or hydric perbromate, HBrO_4 .

There is also a compound of bromine with chlorine called bromous chloride (BrCl_2), and a detonating oily fluid, bromide of nitrogen, analogous to chloride of nitrogen. A fluoride of bromine likewise exists: in fact, bromine unites with all the elementary bodies. Altogether, bromine holds an intermediate position between chlorine and iodine. It can expel the latter element from certain compounds, and is in its turn expelled by chlorine.

If the atomic weight of iodine be added to that of chlorine, and divided by two, the mean is as nearly as possible the atomic weight of bromine.

FLUORINE.

Symbol, F . Atomic weight, 19.

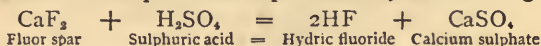
This element appears to have evaded the usual searching powers of the analytical chemist, and for a long time could not be procured in the elementary state. It seems, however, to be satisfactorily determined that it can be liberated from the trammels of combination by acting on dry argentic fluoride or silver fluoride with dry iodine; it then appears as a colourless gas, which

has no power upon glass, and is rapidly absorbed by a solution of potash, but remains permanent over mercury.

Fluor spar is found in Derbyshire and in all the galena (plumbic sulphide) veins which traverse the coal formations of Durham, Cumberland, and other places, and is most frequently crystallized in the cubic form. The red varieties have been called *false ruby*, the yellow *false topaz*, the green *false emerald*, and the blue *false sapphire* and *amethyst*. The variety of fluor spar that becomes phosphorescent when heated is called "chlorophane," from the green light it emits.

Because it has been used by the metallurgists as a flux for ores, particularly those of iron and copper, it derives the name of "*fluor*," from *fluo* to flow; its modern scientific name is calcium fluoride (CaF_2). Fluorine is also contained in the mineral termed cryolite ($3\text{NaF}, \text{AlF}_3$), a double salt of sodium and aluminium fluoride, and an important source of the metal aluminium. As the teeth contain a minute quantity, it is evident that the body is supplied with this element from the foods required for the support of man.

The most important compound is that which it forms with hydrogen—called hydro-fluoric acid or hydric fluoride ($\text{HF}=20$). It is obtained, like hydrochloric acid, by distilling one part of fluor spar with three parts of strong sulphuric acid, and the decomposition is represented by the following equation:



The fluor spar and sulphuric acid must be heated in a leaden retort, or, better still, in one made of platinum, and the vapour, hydric fluoride, is collected in a receiver—usually a bent leaden or platinum tube surrounded with a freezing mixture. The metals, lead or platinum, should be used, as hydric fluoride acts so vigorously on glass.

It would appear from the researches of Louzet that the acid prepared in this way contains water, and by distilling it again with phosphoric anhydride, a colourless gas of a very lung-exciting nature is obtained, which does not act like the ordinary acid on perfectly dry glass. This acid united with two atoms of water increases in specific gravity from 1.060 to 1.150 ($\text{HF}, 2\text{H}_2\text{O}$). It does not undergo any change when distilled, and boils at 248°F . This acid acts upon a great number of metals, its hydrogen being displaced by them. The acid is used for etching on glass, and is now (like other once rare chemical compounds) employed most skilfully in the formation of elegant patterns on that vitreous body.

CARBON.

Symbol, C. Atomic weight, 12.

Every tyro in chemistry is now ready to speak profanely of the diamond as only a bit of hard and nearly pure carbon. The portraits of Faraday and Wheatstone have already been given in this work, and the series is hardly complete without that of the learned man who has lately, like Faraday, passed away from us. Brewster's name is introduced here because, amongst the thousand and one clever papers on scientific subjects that he wrote, we find one devoted to what he terms pressure cavities in the diamond, which will be alluded to hereafter.



I am,
Ever Most Truly Yrs
D Brewster
Attesty, Mcrose
Leaving 16th 1867

FIG. 25.—Portrait and Signature of Sir David Brewster.

David Brewster was born at Jedburg on the 11th December, 1781, and died in 1868. His name will always be associated with the kaleidoscope, and the discussion of other and more abstruse points in the science of optics.

Carbon or charcoal can be obtained from various sources. Bone-black or animal charcoal is obtained by subjecting bones to a low red heat in closed iron cylinders, the volatile matter, ammonia, &c., being allowed to pass into proper receivers.

It is most usefully employed as a deodorizing agent in the purification of raw sugar, &c., and its deodorizing properties and power of condensing the putrid effluvia of decomposing animal or vegetable matter is very well understood, and used in the openings of the shafts of sewers, or, more agreeably, in the filtration and purification of water containing organic matter.

Wood charcoal is now made very carefully from willow or alder, by heating them in closed iron cylinders, and, when prepared in this manner, is used in the manufacture of gunpowder. Common wood charcoal used for heating purposes is prepared in a ruder fashion by the charcoal-burners. Lampblack, or finely-divided charcoal, is obtained by the slow combustion of resin or tar: these bodies yield hydro-carbon, and, as the air is only partially admitted, the hydrogen is removed, forming water, whilst the carbon is deposited. By exposing common lampblack to a red heat in a closed iron vessel, the tarry matter is then thoroughly ignited, and a very pure form of carbon obtained.

Coke, the charcoal of coal, is made in large quantities during the distillation of coal in the manufacture of coal-gas.

A very hard form of charcoal is gradually deposited in the gas retorts, which is used instead of platinum in the nitric acid cell of the voltaic battery, called Bunsen's, and likewise for the terminals of the poles of the voltaic battery in the production of the electric light. This kind of charcoal is sometimes spoken of as graphite; but, when so styled, should be called "artificial," as the real graphite is a natural and nearly pure form of carbon.

Plumbago, black lead, or graphite is a most useful form of mineral carbon: it used to be obtained from the mines at Borrowdale, but is now procured from mines in Asia and other places. The finer kinds of plumbago were formerly boiled in oil, and then cut into tables or pencils; but now the dust or powdered plumbago is compressed and employed extensively in the manufacture of lead pencils. It is also used for brightening grates and other ironwork, and keeping them free from rust. Graphite is now extensively used in the manufacture of very refractory crucibles, and as an anti-friction material.

By combining charcoal with wrought iron, the latter becomes extremely fusible. If this compound of carbon and iron be melted and allowed to cool slowly, it will be covered with scales, which on examination are found to be identical with plumbago or black lead.

Some meteorites contain graphite or black lead, mechanically diffused through the mass of iron which has fallen from the skies.

Brodie has shown that by acting on graphite with an oxidizing agent, such as chlorate of potash and sulphuric acid, a product is obtained that does not present any characteristic different from that of ordinary graphite. If, however, it be heated in a test-tube, it swells up and presents a very remarkable appearance: the graphite partly oxidized gives off steam, and returns again to its original condition. Carrying the oxidizing process still further, the same chemist has converted graphite into graphitic acid ($C_nH_nO_n$). By acting repeatedly on this substance with chlorate of potash and nitric acid, it forms perfectly transparent thin crystals: when a few of these are heated in a platinum dish, incandescence and a slight explosion occurs, and a large quantity of soot is evolved: the graphite, by the roundabout process of oxidation

and conversion into graphitic acid, and subsequent heating, is now changed to ordinary charcoal. The experiment with the graphitic acid is a very curious one, the quantity of charcoal evolved in the form of soot is so enormous.

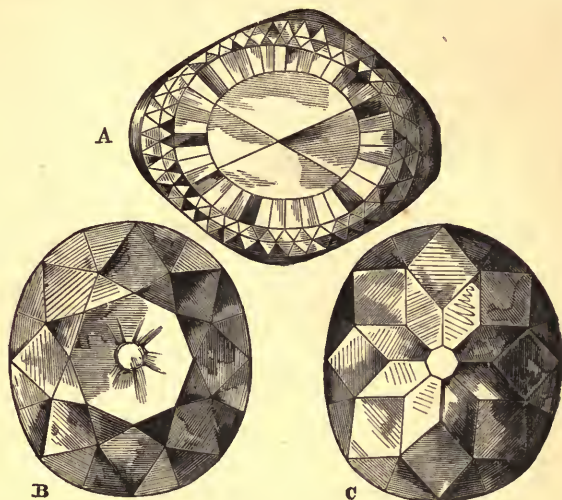


FIG. 27.—*The Koh-i-Noor before and after re-cutting.*

A, the Koh-i-Noor before re-cutting; B, back view of same after re-cutting by Mr. Coster; C, front view after re-cutting.

The diamond, the purest form of natural carbon, is well represented by the most costly of the crown jewels called the Koh-i-Noor.

"The history* of this gem has been so often told that it would be superfluous to give any lengthened notice of it. The Hindoo accounts deduce it from the time of the god Krishna. We know, however, for a certainty that it was in the treasury of Delhi, and was taken at the conquest of that city by Alad-Din. Thence it came into the possession of the Sultan Baber, of the Mogul dynasty, in 1526. This prince esteemed it at the sum of the daily maintenance of the whole world. The jewel was seen by Tavernier among the jewels of Aurungzebe: it had, however, been reduced by the unskilfulness of Hortensio Borgio from 793 carats to 186 carats—the weight it possessed at the Exhibition of 1851. The Emperor Aurungzebe was so incensed that he refused to pay Borgio the sum agreed on for the cutting, confiscated the whole of his possessions, and with great difficulty was persuaded to leave him his head. Nadir Shah, the conqueror of India, by means of an artful trick obtained possession of this stone, and from the hands of his descendants it passed into the possession of Achmed Shah. His son, Shah Sujah, was in turn forced to return it into the hands of Runjeet Singh. After the capture of

* "Diamonds and Precious Stones." By H. Emanuel.

Lahore, at the time of the Sikh mutiny, it fell into the hands of the British troops, who presented it to Her Majesty Queen Victoria on the 3rd of June, 1850.

"This brilliant was shown at the Exhibition of 1851. It then had an irregular form, with several hollows in its sides and base, and showed clear traces of natural cleavage planes; there were also several fissures or cavities in its surface. It was shown to several of the first scientific men of the day, Sir David Brewster among the number, who were of opinion that the stone presented great difficulty in the way of cutting. After much consideration it was entrusted to Mr. Coster, of Amsterdam, who expressed himself confident as to the result of re-cutting; and the event proved the correctness of his judgment, for the stone, though of less weight than before, possesses nearly the same size, and instead of being a lustreless mass scarcely better than rock crystal, it has become a brilliant matchless for purity and fire.

"This diamond now weighs $106\frac{1}{16}$ carats, and forms part of the crown jewels of England."

Sir David Brewster makes the following remarks on the Koh-i-Noor in his paper in the "Transactions of the Royal Society of Edinburgh, 1862," and entitled

"ON THE PRESSURE CAVITIES IN TOPAZ, BERYL, AND DIAMOND,
AND THEIR BEARING ON GEOLOGICAL THEORIES.

"In the Koh-i-Noor diamond, which the Prince Consort kindly permitted me to examine in 1852, I found three black specks, scarcely visible to the eye, but which the microscope showed to be irregular cavities surrounded with sectors of polarized light. In the two smaller diamonds which accompanied the Koh-i-Noor there were also several cavities surrounded with luminous sectors, and the same polarizing structure which indicated the operation of compressing and dilating forces. In order to obtain more information on this subject, I examined nearly fifty diamonds lent me by Messrs. Hunt and Roskell, and in almost all of them I found numbers of cavities of the most singular forms, round which the substance of the stone had been compressed and altered in a remarkable manner. The shapes of the cavities sometimes resembled those of insects and lobsters, and the streaks and patches of colour in polarized light were of the most variegated kind. It seems, indeed, to be a general truth that there are comparatively few diamonds without cavities and flaws, and that this stone is a fouler stone than any other used in jewellery. Some diamonds, indeed, derive their black colour entirely from the number of cavities which they contain, and which will not permit any light to pass between them.

"Having found in diamonds so many pressure cavities, as we may call them, round which the substance of the stone is compressed, I had some expectation of finding them in other minerals; and in re-examining the numerous plates of topaz in my possession, I succeeded in discovering several under such remarkable circumstances that I submitted a description and drawings of them to this society in 1845. In searching for these phenomena with the polarizing microscope, we first observe four sectors of polarized light; and if the magnifying power is sufficient, we shall find in the centre of the black cross that separates the sectors a small opaque speck, which is the cavity or seat of the compressing force. This cavity is frequently of a rhomboidal form, and often only of the $\frac{3}{1000}$ th or $\frac{4}{1000}$ th of an inch in diameter. It is always opaque, as

if the elastic substance which it contained had collapsed into a black powder; and I have met with only one cavity in which there was a speck of light in its centre. The polarized tint of the luminous sectors varies from the faintest blue to yellow-green; blue and red tints of higher orders. In most cases the elastic force has spent itself in the compression of the topaz, the cavity remaining entire and without any apparent fissure by which a gas or liquid could escape. I have discovered, however, other cavities, and these generally of a larger size, in which the sides have been rent by the elastic force, and fissures, from one to six in number, propagated to a small distance around them. These fissures have modified the doubly refracting structure produced by compression, but the gas or fluid which has escaped has left no solid matter on the faces of fracture."

The "Chemical News" gives, however, a brief commentary on the above, by stating that "Mr. Sorby finds that the supposed cavities in diamonds described by Brewster are, in reality, enclosed crystals; and the conclusion arrived at, from the consideration of the whole structure of the diamond, is not opposed to its having been formed at a high temperature. The crystals enclosed in diamonds are frequently seen to be surrounded by a series of fine radiating cracks, which are proved to be the result of the contraction suffered by the diamond in solidifying over the enclosed crystal; and this explanation has been artificially verified by examining crystals formed in fused globules of borax and glass cooled slowly, when the same phenomena are seen."

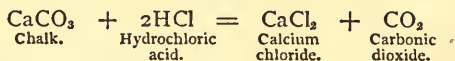
COMPOUNDS OF CARBON WITH OXYGEN.

Carbonic Acid or Carbonic Dioxide.—As all *acids* are now supposed to denote a salt of *hydrogen*, even the term "acid" when applied to carbonic acid would be incorrect, because the latter contains no hydrogen. Chemists, however, have met this difficulty by retaining a part of the name by which it is so well known, viz., carbonic, and adding thereto "anhydride," to show that it has no hydrogen.

Carbonic anhydride ($\text{CO}_2=44$; specific gravity, 1.529).—This gas, as already stated, is contained in atmospheric air, and is easily detected by exposing some lime-water in a dish to the air. A pellicle of carbonate of lime, calcic carbonate, or chalk, is formed, and therefore a compound of carbonic dioxide and calcium oxide.

This gas is easily obtained by acting on chalk, marble, limestone, oyster-shells, or whiting, by dilute nitric, hydrochloric, or sulphuric acids. Acetic acid (vinegar) may also be used.

The following equation is a simple example of decomposition:



Calcium carbonate and hydrochloric acid give carbonic dioxide, water, and calcium chloride.

Carbonic dioxide has a slight acidulous odour, is colourless, transparent, and half as heavy again as atmospheric air. It was originally discovered by Dr. Black, who called it *fixed air*. It is perfectly unrespirable. If an attempt be made to breathe it, the epiglottis closes spasmodically, and suffocation occurs. It is a poison, and appears to act as a narcotic when mixed with

a large quantity of air, causing drowsiness, insensibility, and death; hence the danger of breathing an atmosphere contaminated with carbonic acid.

In sinking deep wells and pits the air may become foul from the breath of the workmen, or from other causes. The bad air, containing carbonic dioxide, is, however, soon removed by letting down a closed inverted umbrella, which, opening with a spring, is pulled quickly up and again lowered, until it is found that a candle will burn in every part of the pit or well.

When the air of a room contains $\frac{1}{10}$ per cent. of carbonic dioxide, it is no longer fit for respiration, and the bad effects of this dilute poison is shown by the fainting of delicate women, who are sometimes peculiarly sensitive to the action of this poison.

In the fermentation of beer large quantities of this gas are evolved; and many fatal accidents have been caused by the foolish carelessness of the brewers in entering vats too soon after the beer has been drawn off. The chokedamp of mines owes its life-destroying powers to the same cause—the presence of carbonic dioxide, which follows the explosion of fire-damp and air.

It is an erroneous idea to suppose that carbonic dioxide, when once mixed with air, can separate itself and fall to the lower part of the room: it remains mixed by the law of diffusion, and the value of the law is thus seen to be very great; as it is quite possible to conceive that a separation might take place in a mechanical mixture of air and carbonic dioxide if this were not the case.

A solution of carbonic dioxide in water is called “soda-water,” this beverage having derived its name, not from the gas which imparts the refreshing, sparkling character, but from the few grains of sodium carbonate added to the fluid contents of each bottle.

By a pressure of 38.5 atmospheres, and at a temperature of 32° F., carbonic anhydride is liquefied. It does not in this state dissolve freely in water; but if mixed with alcohol, ether, turpentine, or carbonic disulphide, solution occurs very rapidly, and this fact is taken advantage of to produce very low temperatures. When the liquid acid is allowed to escape from the apparatus devised and constructed by Mr. Robert Addams, the cold produced is so intense that the liquid acid solidifies in beautiful snow-like flakes, which may be collected in a proper box. If this solid carbonic dioxide is mixed with ether, the temperature sinks to—148° F. or 100° C., and if mercury is placed in the solution, it solidifies. A number of very pleasing experiments may be performed with solid carbonic dioxide, such as freezing water in a red-hot vessel. This experiment was originally performed by Faraday by placing some of the solid gas into a red-hot crucible, and, after pouring in a little ether, the mercury is quickly added, and in a few seconds assumes the solid state. Mercury freezes at a temperature of 40° below the freezing-point of water.

The ordinary gas is easily collected by displacement, and may be poured from one vessel to another. It extinguishes flame, and this test, with that of lime-water, enables the experimentalist to devise a number of amusing experiments, in which the breath, the gas from soda-water, or the combustion of charcoal or the diamond, are found to put out the light, and to change the lime-water milky white from the formation and precipitation of chalk. Carbonic dioxide gas may be drawn off by a syphon, or collected in a large jar and allowed to run out of a tap. If the jar is a wide-mouthed one, a child's india-rubber ball, or a balloon distended with air, will not sink in the gas, but remains floating, like a cork in water. 100 cubic inches of carbonic dioxide weigh 47.303 grains at 60° F., 30 in. bar.

A solution of the gas in water reddens blue litmus-paper, which is again restored to its original colour by boiling the paper in water, because the carbonic acid gas is driven off by the heat.

It is partly the carbonic dioxide dissolved by the rain which gradually filters through the strata, and dissolves the calcium carbonate and other matters found in spring-water. Carbonic dioxide is also produced in water by the oxidation of the organic matter by the oxygen of the air. Oxygen and organic matter in solution in water react upon one another, and carbonic dioxide is produced, whilst the oxygen originally dissolved in the water is reduced in quantity.

Various ingenious propositions have been made to enable persons to go with impunity into an atmosphere containing carbonic dioxide or other dangerous gases, or to attend on large voltaic batteries where nitrous fumes are evolved. The most practical and thoroughly useful contrivance is that of M. Galibert, and called by him the "Patent Respiratory Apparatus," being a most important



FIG. 28.—*Galibert's Apparatus.*

and valuable invention for the protection of life and property against danger arising from fire, also of persons exposed to danger from exhalations of gas, foul air in mines, sewers, &c., &c. It is simple, cheap, and effective.

This invention has been successfully introduced throughout the French empire, and the inventor has obtained many prizes and medals in acknowledgement of its merits.

A reservoir, of the capacity of five cubic feet, made of stout canvas, and

fireproof, is filled with air by means of a small bellows belonging to the apparatus, and placed on the back of the operator, as shown in the drawing, being suspended from braces passed over his shoulders, and further held in position by a belt round the body. There are india-rubber tubes, the two ends of which are inserted into the reservoir, the operator holding the other end in his mouth by means of a mouthpiece of horn to which they are attached, thus enabling him to breathe freely from the supply of air drawn through the tubes from the reservoir, without any inconvenience from dense smoke or poisonous gases.

The eyes of the operator are covered with goggles, so fitted as to effectually protect them from any gas or smoke, and the nostrils are closed by a small and simple instrument for that purpose.

The fire department of Paris has provided all its stations with the respiratory apparatus of M. Galibert. The city of Paris has adopted them, after experiments, for disinfecting sewers, &c.; the gas companies of Paris, and of all the large towns; the Transatlantic Steamship Company, many railway companies, the principal mining companies, and a great number of towns, for use in the fire departments, having adopted them after making decisive experiments.

These experiments have been described by the Conseil d'Hygiène et de Salubrité de Paris, by the Annales des Mines, et des Ponts et Chaussées, the "Moniteur," "Constitutionnel," "Presse," "Mondes," and all the journals of the cities and towns in which experiments with this invention have been made.

It has already been the means of saving nearly one hundred lives, and the inventor has received acknowledgments of its merits by numerous prizes and medals from public institutions. It is perfectly simple in its use, and the price is so low as to place one or more within the reach of all persons having property to protect.

The "Times," speaking of the invention, says,

"A very interesting and successful experiment was tried in Portsmouth Dockyard by M. Galibert, a Frenchman, the inventor of an apparatus to enable the wearer to breathe freely in the midst of the most dense smoke arising from a fire. Rear-Admiral Wellesley, Admiral Superintendent of the yard, the Hon. Captain Egerton, Captain W. Chamberlain, and the principal officers of the dockyard were present in the foundry, the drying-room of which was appropriated for the trial, and in which a quantity of straw, shavings, oakum, &c., had been placed, and which at three o'clock was ignited, the only aperture (the door) being then closed, so that the place was soon filled with a dense volume of smoke. M. Galibert then produced the apparatus, which consisted of a canvas bag, fireproof, which he inflated with air by a small pair of bellows; two gutta-percha tubes were affixed, at the end of which was a mouthpiece, which fitted to the teeth, the nostrils being at the same time closed by a small spring. The bag was then slung on his back. Being thus prepared, he entered the room, the door closed upon him, and there he remained eight minutes and fifty seconds, at the expiration of which time the door was opened, and he came out apparently without the slightest exhaustion; after which one of the police constables, John Lacy, No. 157, volunteered to try the experiment, which the admiral permitted, and being fully equipped and instructed by the inventor, he entered the room, where he remained three minutes—sufficiently long to test the utility of the apparatus. One of the labourers followed, and remained six minutes, and both men stated that they found no inconvenience

while in—they could breathe as freely as in the open air, and could have remained any length of time. Subsequently a ladle was heated, in which a quantity of sulphur was put, thus rendering the smoke still more dense; but M. Galibert, after being in six minutes, returned again without the slightest inconvenience. The thermometer was at 91° ."

CARBONIC OXIDE.

Carbonic Oxide (symbol, CO; atomic weight, 28).—When carbonic dioxide is passed through red-hot charcoal, it parts with one atom of oxygen, which unites with another of carbon to form carbonic oxide.



This gas is even more poisonous and insidious than carbonic acid, and is produced in considerable quantities during the burning of bricks, where the conditions are favourable for the passage of carbonic acid gas through red-hot charcoal (the cinders called "breeze") with which the bricks are burnt.

By boiling crystals of oxalic acid with strong sulphuric acid, the former is decomposed into carbonic acid and carbonic oxide (CO_2 and CO), the elements (H_2O) which form water being removed by the sulphuric acid.

Carbonic oxide burns with a lambent blue flame, and is converted into carbonic acid. The former is lighter than the latter, and has a specific gravity of 0.967.

COMPOUNDS OF CARBON WITH HYDROGEN.

To the department of organic chemistry belongs the most numerous portion of the hydro-carbons. There are, however, two compounds of carbon and hydrogen which deserve special notice here:

Light carburetted hydrogen (CH_4); Heavy carburetted hydrogen (C_2H_6).

Marsh gas—firedamp—light carburetted hydrogen, methyl hydride (CH_4)—so dangerous in coal-mines because the gas does not possess any odour to warn the miner of its presence—has no colour or taste, and is evolved from stagnant pools and ditches where dead leaves accumulate and decompose.

Soda and sodium acetate heated together yield sodium carbonate and light carburetted hydrogen gas.

Olefiant gas—heavy carburetted hydrogen, ethylene (C_2H_4)—is an important constituent of coal-gas, to which it imparts its chief illuminating powers. Methyl hydride burns with a bluish-yellow flame, whilst olefiant gas burns with a luminous and somewhat smoky flame, betraying the excess of carbon it contains; in fact, this gas contains twice as much carbon as marsh gas united with the same molecule of hydrogen. It is prepared by carefully heating one part of alcohol with five of sulphuric acid: the elements of water are removed by the latter, and olefiant gas (C_2H_4) evolved. It is called olefiant from the Latin *oleum*, oil, and *fio*, to make; because the associated Dutch chemists, Brandt, Dieman, Troostwick, and Laurenberg, in the year 1796, found that when it was mixed with chlorine gas, a peculiar liquid resembling a heavy oil was produced.

Both of these hydro-carbon gases are contained in coal-gas, with other compounds of carbon, and various impurities which it is the duty of the "gas-works" to remove before the gas is supplied to the consumer. But the consideration of such an important theme as coal-gas would demand more space than the limits of this work will permit.

BORON.

Symbol, B. Atomic weight, 10.9.

Sir Humphrey Davy proved this to be an element, and the base of boracic acid, in the year 1807. Boracic acid is obtained from borax, so called from the Arabic *buruk*, which signifies *brilliant*.

Wohler and Deville give the following directions for the preparation of amorphous, dull, olive-green boron in the state of powder: 150 grammes of fused boracic anhydride (boracic acid, B_2O_3), are coarsely powdered and mixed rapidly with 90 grammes of sodium cut into small pieces. The mixture is then introduced into a cast iron crucible previously heated to bright redness; 70 or 80 grammes of solid and previously fused sodium chloride are placed upon the top of the mixture, and the crucible is covered. As soon as the reaction is over, the still liquid mass is thoroughly stirred with an iron rod, and poured whilst red hot in a slender stream into a large and deep vessel containing water acidulated with hydrochloric acid. The pulverulent boron is then collected on a filter, and washed with acidulated water till the boracic acid is got rid of; after which the washing may be continued with pure water until the boron begins to run through the filter. It is finally dried upon a porous slab without the application of heat.

Crystallized Boron.—In order to convert the amorphous into the crystallized form, the same chemists adopt the following method:

"A small Hessian crucible is lined with the powder or amorphous boron, made into a paste with water, the boron being pressed in strongly, as in the ordinary mode of lining a crucible with charcoal. In the central cavity a piece of aluminium, weighing from 6 to 9 grammes, is placed; the cover is luted on, and the crucible enclosed in a second, the interval between the two being lined with recently ignited charcoal. The outer crucible is next closed with a luted cover, and the whole exposed for a couple of hours to a heat sufficient to melt nickel; the temperature is then allowed to fall, and when cold the contents of the inner crucible are digested in diluted hydrochloric acid, which dissolves out the aluminium; beautiful crystals of boron are left, generally transparent, but of a dark brown colour.

A quantity of *scales* of the so-called graphitoid boron—an alloy of boron with aluminium (B_2Al)—are formed at the same time in pale copper-coloured opaque plates.

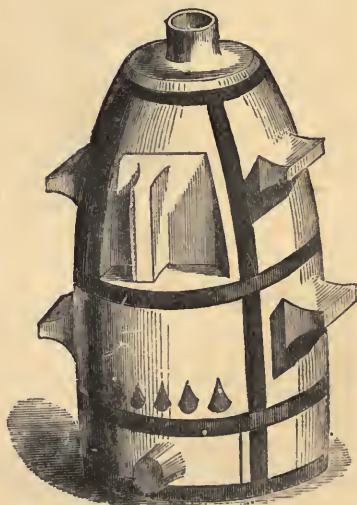


FIG. 29.

Useful Furnace for Crucible operations.

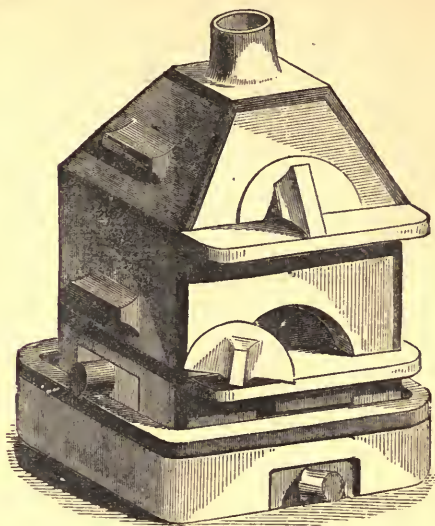


FIG. 30.—*Strong Fire-clay Furnace.*

Boron, like carbon and silica, exists in three conditions, viz., amorphous, crystalline, and graphitoidal. Crystallized boron has a specific gravity of 2.68, and Deville exhibited crystals of the octohedral form hard enough to scratch the ruby. In the remarks on silicon reference will be made to the manufacture of artificial precious stones.

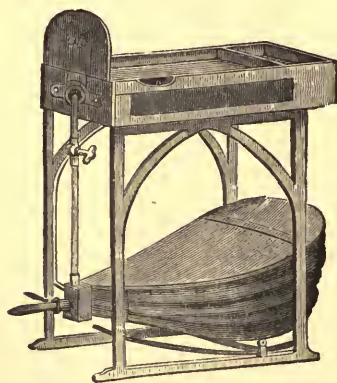


FIG. 31.—*Forge, Bellows, and Iron Tray,*
For small operations where an intense heat is required.

The most important compound of boron and oxygen is boracic trioxide, (boracic acid, B_2O_3 .) It is obtained from the volcanic districts of Tuscany, which puff out jets of steam and gas: they contain small quantities of boracic acid, and are condensed and dissolved in the small lakes and lagoons surrounding the mouth of the jets. The very weak solution thus naturally formed would involve great expense for coal or other fuel if evaporated in the ordinary way; but Nature gives with the weak solution of boracic acid natural steam-jets, and these are used to evaporate the water of the

lagoons. From borax ($\text{Na}_2\text{B}_4\text{O}_7$) boracic acid is procured by dissolving four parts of pure borax in boiling water, and then adding sulphuric acid equivalent to one-fourth of the weight of the borax. Sodid sulphate is formed, and bo-



FIG. 32.—*Gas-burner, and Platinum Crucible and Crucible Jacket,*
For fusing bodies not requiring a high temperature.

racic acid crystallizes out on cooling in pearly-looking scales: these are washed with ice-cold water, dried, and fused in a platinum crucible. The fused crystals are then re-dissolved in four times their weight of boiling water, and the boracic acid crystallizes on cooling in a state of purity.

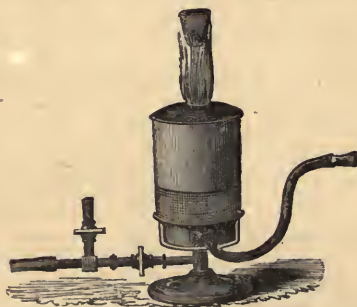


FIG. 33.—*Dr. Normandy's Mixed Air and Gas-burner,*
With a blowpipe jet in centre to urge flame on crucible.

There is a trifluoride of boron (BF_3) and a boric nitride or nitride of boron (BN), for boron possesses the remarkable property of combining with nitrogen at a red heat.

SILICON.

Symbol, Si. Atomic weight, 28.

A non-metallic substance (at present), whose existence in flint (*silex*) was suspected by Sir H. Davy, silicon, like boron, may exist without form, *i.e.*, amorphous; as, for instance, when obtained by passing the tetra-fluoride of

silica into water, producing an acid solution. The tetra-fluoride is obtained by heating a mixture of sand with powdered fluor spar and sulphuric acid. The gas must be passed through a cup containing mercury, or the deposited silica hydrate ($\text{H}_2\text{OSi}_2\text{O}_3$) would soon close the tube, and, stopping the further exit of the gas, would cause an explosion to take place.

The acid liquor neutralized with a solution of caustic potash yields potassic silica fluoride ($2\text{KF}, \text{Si}_2\text{F}$).

When this salt is dried and mixed with nearly its own weight of sodium, and heated in a glass tube, sodium fluoride is formed, whilst silicon is reduced; and when the whole is thoroughly washed, collected, and dried, a dull brown powder is obtained.

Silicon, like carbon and boron, may be obtained in three conditions—amorphous, graphitic, and crystalline. In the amorphous state it can be burnt in oxygen, and then forms silica. Crystals of silica are obtained by putting into a red-hot crucible a mixture of three parts of potassic silica fluoride with one of metallic sodium and four of zinc: of course the perfection of manipulation requires that the sodium shall be minced and the zinc granulated. When cool, the crystals deposited on the zinc are found to be silica, which can be separated from the former by hydrochloric acid, and subsequently by boiling nitric acid. Silica thus obtained will scratch glass, and has a specific gravity of 2.49.

The graphitic form of silica is obtained by heating the amorphous silica at a high temperature.

The compound of oxygen and silica which specially demands consideration is silicic dioxide or silica—the substance which, next to oxygen, is the most abundant in nature. It not only exists as silicic dioxide, nearly pure, as a mineral ($\text{SiO}_2=60$), but is abundantly distributed in the form of silicates through the mineral productions of the known crust of our globe. Primary rocks owe their hardness chiefly to the presence of silicic dioxide.

Silica occurs in two states—amorphous when prepared by passing the tetra-fluoride of silica into water, as already described. The deposited silica may be washed, dried, and heated to a great heat, and then appears perfectly snow-white.

Common flint stones, heated red hot and plunged into water, afford a white powder which is nearly pure silica. Any artificial amorphous form of silica is easily dissolved in alkaline solvents, hence the manufacture of water-glass.

The crystalline forms of silica quartz are legion. "Quartz is composed of pure silica, generally combined with minute proportions of metallic oxides, from whence the varied and brilliant colours it frequently exhibits are derived. It is a most abundant mineral, forming extensive veins and masses in primitive and transition rocks, and consequently is diffused over almost every quarter of the globe. It is an essential constituent of granite, gneiss, mica-slate, and other allied rocks, and in the form of sand forms nearly the whole of the mobile soil of the sterile desert. In South America quartz has been observed by Humboldt in mountain masses or beds, many hundred feet in thickness. Its specific gravity varies from 2.5 to 2.8, and is 2.65 in the purer varieties.

"Quartz consists of many varieties, differing much in external appearance, all of which readily scratch glass, and equal 7 in Prof. Moh's scale of hardness. It is infusible *per se* before the blowpipe, but with soda fuses with intumescence into a transparent glass, and is insoluble in all acids excepting hydro-fluoric acid: when pulverized it is slightly soluble in a solution of caustic potash.

Quartz occurs massive and crystalline, also fibrous, stalactite, granular, spongi-form, pseudo-morphous, &c.*

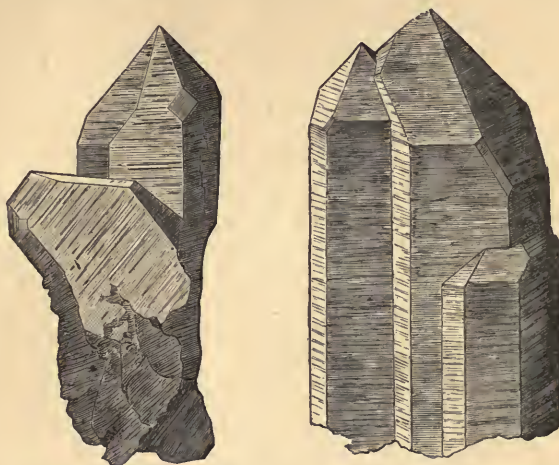


FIG. 34.—Single Crystal of Quartz. FIG. 35.—Group of Crystals of Quartz.

The following are the names used by mineralogists for crystallized quartz: Rock crystal. Dragonite. Quartz, *Phillips Brook and Miller, &c.*; Quartz *Hauy Naumann, Werner, Haidinger, Hausmann.* Rhombohedral Quartz, *Moh's.* Whitestone of the jewellers. Berg crystal.

Silica	. 99'37
Alumina	. trace

99'37 Bucholz.
Specific gravity 2'653 Bendant.



FIG. 36.

A, Primary form of crystal; B, the usual form, hexagonal prism, terminated by hexagonal pyramids.

There is a remarkable combination of silicon and hydrogen (H_4Si) called siliciuretted hydrogen, which, like phosphuretted hydrogen, takes fire spon-

* "Elementary Treatise on Quartz and Opal." By S. W. Traill, F.G.S.

taneously in the air, forming silica and water. A silicic nitride, sulphide, chloride, and fluoride are also amongst the carefully recorded compounds of silica.

The "Literary and National Gazette" thus describes the manufacture of gems, and the colouring and improving of stones belonging to the quartz class.

HOW GEMS ARE MANUFACTURED.

"That many things glitter which are not gold is well known; but do the wearers of jewellery know that the bright and beautiful colours exhibited by most of their much-prized gems are purely artificial? Nature supplies the raw material, and art steps in to embellish it. The brilliant necklace or bracelet, which, with the native hue of the stone, would by no means be considered ornamental, becomes matchless in tint and lustre after passing through the hands of the artificer. Your chemist, always discovering something and always ready with marvellous transformations, is truly a remarkable personage. He is jealous of his secrets, but not always able to keep them. If he could set a seal on his doings, our readers would not have been entertained with the present article, in which we shall take leave to reveal some of his processes.

"Let us begin with agate—rather a common stone, found almost everywhere, and in numerous varieties, among which are the chalcedony, cornelian, onyx, sardonyx, and heliotrope. They all consist principally of quartz, and are more or less pellucid. In some places they are surprisingly abundant. One of these places is Oberstein, some thirty or forty miles up the valley of the Nahe, a region not often visited by summer tourists, yet interesting enough to repay him who shall explore its devious byways and paths along the river. At the village just mentioned, and at Idal, four miles distant, formations of coarse red conglomerate are met with, interposed with trap and greenstone; and in soft strata in these rocks agates are found in considerable quantities. The workings may, indeed, be called agate-quarries, for they are carried on in the precipitous side of a hill; and to him who sees them for the first time there is something remarkable in the species of industry created by the presence of the stones.

"The nodules of agate, as they come from their long-undisturbed bed, are generally of an ashen-grey colour. The first operation in the process of transformation is to wash them perfectly clean; then to put them into a vessel containing a mixture of honey and water, which, being closely covered, is plunged into hot ashes for two or three weeks. The essential thing is to keep the liquid from boiling, but at a high temperature. After a sufficient interval the stones are taken out, cleansed, passed through a bath of sulphuric acid, and then they undergo a second course of roasting in the hot ashes.

"To produce a colour in the stones, it is necessary they should be penetrated by some carbonizable substance. This is effected by the honey, which, under the influence of long-continued heat, finds its way into the interior of the crystal, where its carbonization, if not complete in the first instance, is finished by the sulphuric acid. Some lapidaries use olive oil instead of honey. The shade of colour depends on the porosity of the layers of the stone: the most porous become at times perfectly black. Some are coloured in two or three hours, others in as many days, others in a week or two, and some resist all attempts to change their natural hue. Some, when they are taken out of the pan, are found to be a rich dark brown, or chocolate; others, again, having

been penetrated by the colouring matter between the layers, are striped alternately white, grey, and brown, like the onyx and sardonyx.

"By soaking the stones in a solution of sulphate of iron, and then placing them for a few hours in the oven, a fine cornelian red is produced in the porous layers, while those not porous remain unaltered. Thus it not unfrequently happens that very coarse and common stones—muddy yellow or cloudy grey—which in their natural condition would be valueless, are passed off as stones of the first quality. It is only within the last forty years that this process has been known in Germany; but the Italian lapidaries were acquainted with it centuries ago. Hence we can account for the exquisite colour of antique cameos and other ornaments once numerous in the cabinets of Italy, and now to be seen in museums and private collections in all parts of the world.

"The dealers, when making their purchases of what we may call the raw material, select what appears to be a desirable piece, and chipping off a minute portion, they moisten the exposed surface with the tongue, and watch the absorption of the moisture. If regular and equal, the stone is good for an onyx; if not, it is added to the heap of inferior varieties. This, however, is but a rough-and-ready test, and not always decisive.

"The pores of the stones by which the colour is conveyed and retained are visible with the microscope, and the effect of various tints is produced according as the light falls upon them at different angles. The rainbow agate is full of minute cells, which, when exposed to the sun, produce prismatic colours, as is observed of the striæ of mother-of-pearl. To detect cavities in the stones, they are soaked in water, which, slowly penetrating, reveals the hollows. Some already contain water when first found; and it is a remarkable fact that, if kept in a dry place, the water disappears, but without leaving the slightest traces of moisture on the surface, and the stones can only be refilled by boiling them.

"Balls of striped red chalcedony are much prized: a large one weighing 100 lb. was found in 1844 near Weisselberg, and was sold in the rough for 700 guilders. Some kinds of chalcedony are made to appear of a citron yellow, by a two days' roasting in an oven, and a subsequent immersion in a close hot bath of spirits of salt for two or three weeks. A blue colour, which has all the effect of a turquoise, is also produced, but the particular colouring process has hitherto been kept a secret. These stones which are naturally coloured are at times roasted, to heighten the tint and add to its permanency. The Brazilian cornelian becomes singularly lustrous under the process; the explanation being that the long-continued action of heat removes the oxyhydrate of iron contained in the stone, leaving it with a clear brightness diffused through the whole mass. The smallest stones are roasted before polishing, but the large ones, of which saucers, vases, cups, plates, &c., are made, are first cut into the required shape and thinness—otherwise they fly to pieces when exposed to heat. After all the colouring operations have been gone through, the stones are ground on a wheel soaked in oil for a day, to conceal the fine scratches and give a good polish, and then cleaned off with bran.

"Those who examined the collection of gems and works of art from rare stones in the Great Exhibition of 1851, will remember the elegant onyx vases of different colours—some streaked with white natural veins; the cups of red chalcedony; a chain of the same substance in large square links of different colours and without visible joints; besides other objects so beautifully finished that a prize medal was awarded to the manufacturers.

"So far we have been treating of methods by which Art assists Nature: we come now to the gems that are not found in the side of a quarry, but formed in the chemist's laboratory. Before the days of Berlin wool and crochet-work, young ladies used to amuse themselves by making crystalline baskets and trays, as ornaments for the mantelpiece; but they had first to dissolve their alum. The chemist works by other means, and, especially since the application of electro-galvanism to his processes, there is something really wonderful in the results. He produces crystals at pleasure, and in lumps that would astonish those who once laboured so hard in search of the Philosopher's Stone. A few years ago M. Ebelmas laid before the French Academy of Sciences specimens of artificial quartz—some white, others blue, red, and violet; and by mixing chloride of gold with the silicic acid used in the composition, he produced a mass traversed throughout with delicate veins of gold, similar to the lumps brought from Australia and California. By a modification of his process he produced hydrophane—that species of opal which is transparent only when immersed in water—and specimens also of the allied crystal, hyalite. In this operation silicic ether and moist air are principally employed; and a variety of colours could be imparted by the admixture of different coloured alcoholic solutions. Chloride of gold produces a beautiful topaz yellow; and by exposing the crystal for a time to light, the gold is dispersed through it in flakes, as an aventurine; and kept in sunlight, the flakes change to a violet or rose-colour, and become transparent. In this fact we have an extraordinary instance of molecular action—the distribution of metallic scales through a solid mass; one which, as some geologists suppose, helps to throw light on the mode of formation of rocks and minerals. That pieces of wood, plants, and animal substances will become silicified, or, as is commonly said, petrified, is well known; and though often wondered at, the diffusion of the gold flakes through the crystal is yet more marvellous."

SELENIUM.

Symbol, *Sc.* Atomic weight, 79.5.

This element is intimately connected with, and allied to, sulphur, and was discovered by Berzelius, in 1817, in the refuse of a sulphuric acid manufactory at Gripsholm, near Fahlun, in Sweden. It has been found in the natural state at Culebras, in Mexico.

The vitreous form of the element, obtained by melting this substance, is well shown in the medallion portraits of Berzelius, which used formerly to be very common, and are cast in selenium (Fig. 37). When selenium is dissolved in carbonic disulphide and deposited from this solution, it assumes the crystalline form. There is evidently a change in density when selenium is crystallized, because the element in the fused or vitreous state has a specific gravity of 4.500, and 4.700 in the crystalline form; moreover, the latter melts at a temperature of 217° F., whilst the former softens at a heat a little above the boiling-point of water. Dr. Miller says the statements regarding the point of fusion of selenium are discordant, owing to its power of existing, like sulphur, in several distinct modifications. It has neither taste nor smell, and when examined by transmitted light, in a finely-divided state, has a red colour.

Fused selenium forms a solid of a deep brown colour, with a glassy fracture

and metallic lustre. It is insoluble in water, and is a non-conductor of heat and electricity. It burns in the air with a bright blue flame, emitting a peculiar odour.



FIG. 37.—Portrait of Berzelius, the Discoverer of Selenium.
(From a cast in that substance.)

The compounds of oxygen and selenium are selenic dioxide, or selenious anhydride (SeO_2), selenic trioxide (SeO_3),—the latter has not yet been isolated, although the acid and salts corresponding with it are known,—selenic acid, or dihydric selenate (H_2SeO_4). There are consequently *selenites* and *seleniates*.

Seleniuretted hydrogen, or dihydric selenide (H_2Se), is prepared by the action of an acid on a selenide, and gas is obtained which painfully stimulates the nose, destroying for some hours the sense of smell; indeed, a very small bubble of the gas let into the nostrils of the operator deprives him, says Griffiths, so completely of the sense of smell, that he cannot discover even the extremely pungent odour of ammoniacal gas. This compound corresponds in its properties with that nauseous-smelling gas called sulphuretted hydrogen.

There are two compounds of selenium and chlorine, Se_2Cl_2 and SeCl_4 ; the former is a brown volatile fluid, and the latter a volatile white crystalline mass.



SULPHUR.

Symbol, S. Atomic weight, 32.

The greater quantity of sulphur used in England comes from the volcanic regions of Sicily, near the base of Mount Etna, and in other places on the borders of the Mediterranean. The native sulphur is purified by sublimation, and the apparatus employed is shown at Fig. 38, and is thus described by Müspratt:

"In 1815 a manufacturer named Michel, of Marseilles, devised an apparatus which, with some slight modification, is in use up to the present day. Fig. 38 represents the retort wherein the sulphur is converted into vapour, and a condensing-chamber into which this is converted into solid sulphur. The apparatus, as in the drawing, consists first of a retort, C, beneath which is a furnace, A: this retort is filled with liquid sulphur from the reservoir, B,

wherein the crude sulphur is melted by the waste heat of the furnace to facilitate its introduction into the retort. When the retort has become sufficiently hot, the sulphur begins to pass as vapour through the tube or opening D into the condensing-chamber, E. This chamber is built entirely of brick, with a well-cemented brick floor. On its upper part a small chimney is erected; this chimney contains a small wooden valve or door, capable of opening outwards to allow the expanded air to escape, and, in case of explosion, to allow the gases produced immediate exit. This apparatus, when cold, allows solid sulphur to form at once in the shape of the ordinary commercial flowers of sulphur; the vapours immediately coming in contact with the cold chambers.

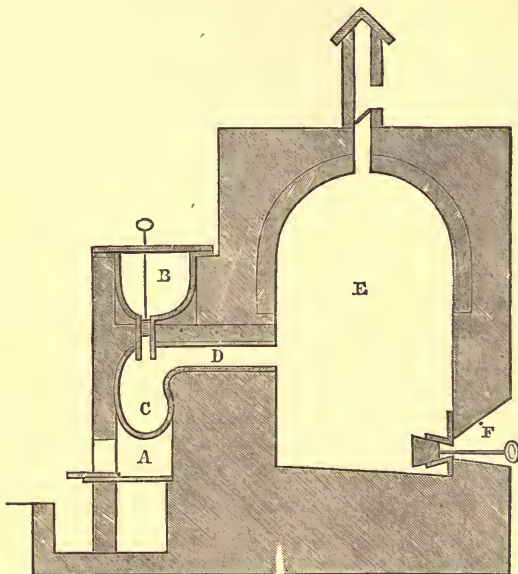


FIG. 38.—*The Subliming Apparatus used in the purification of crude Sulphur.*

are chilled, and fall as a minutely-divided solid. These flowers, as they are called, are removed before the chamber gets hot, which is the case after a few days' working. The whole of the heat which the sulphur has taken up in order to become vapour being given out to the walls, they thus acquire such a high temperature as to fuse sulphur; therefore it can no longer become solid, but condenses on their surface in a liquid form, and falls down to the bottom, where it collects. When the operator is satisfied that sufficient has distilled over, he proceeds to remove it; this he does by the plug apparatus, F, which is only an iron plug with a long handle, and by pushing the plug inwards he opens the passage for the flow of liquid sulphur, which runs into suitable moulds to form the sticks or rolls of commerce. The residue is raked out of the retort, which

is immediately charged again by removing the plug that closes the tube between the vessel B and the retort."

Native sulphur occurs in the amorphous and crystalline states. When pure, sulphur is insoluble in water, tasteless, but emits a peculiar odour. It is very inflammable, and takes fire at a temperature between 450° and 500° F., producing the pungent and very suffocating gas called sulphurous anhydride (SO_2).

Although chiefly used in the manufacture of oil of vitriol, sulphur is employed extensively in the manufacture of lucifer matches, and is an important constituent of gunpowder. It is also used for bleaching silk, flannel, feathers, &c.

There are three modifications of sulphur: first, the natural crystals, the octohedron with a rhombic base, and two other allotropic conditions, viz., one obtained by melting and crystallizing sulphur in needles, and the third a red amorphous substance, obtained by pouring melted sulphur into water.

The compounds of sulphur with oxygen are two in number:

Sulphurous anhydride . . . $\text{SO}_2 = 64$.

Sulphuric anhydride . . . $\text{SO}_3 = 80$.

The oxyacids of sulphur are very numerous:

Sulphurous acid . . . $\text{H}_2\text{SO}_3 = 82$.

Sulphuric acid . . . $\text{H}_2\text{SO}_4 = 98$.

Hyposulphurous acid . . . $\text{H}_2\text{S}_2\text{H}_2\text{O}_4 = 132$.

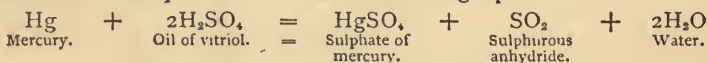
Dithionic acid . . . $\text{H}_2\text{S}_2\text{O}_6 = 162$.

Trithionic acid . . . $\text{H}_2\text{S}_3\text{O}_6 = 194$.

Tetrathionic acid . . . $\text{H}_2\text{S}_4\text{O}_6 = 226$.

Pentathionic acid . . . $\text{H}_2\text{S}_5\text{O}_6 = 258$.

Sulphurous anhydride, or sulphuric dioxide (symbol SO_2 , atomic weight 64), are the scientific names of the pungent suffocating fumes given off when sulphur is burnt. It is easily prepared by boiling 2 oz. of quicksilver with 3 oz. of sulphuric acid; the former deprives the latter of a portion of its oxygen. The reaction that takes place is shown in the following equation:



Copper may be used instead of mercury, but when a small quantity of sulphurous anhydride is required, the evolution of the gas is much quicker with the latter metal.

Sulphurous dioxide has a specific gravity of 2.247, and therefore is easily collected by displacement or over mercury in the mercurial trough. The gas should be washed by allowing it to bubble through a little water placed in a Woolfe's bottle.

Sulphurous dioxide has no colour, and cannot be respired. When subjected to a temperature of -10° F., by means of a freezing mixture of snow and salt, it is reduced to the liquid state at the ordinary pressure of the air.

After collecting the liquid gas in a strong tube, the latter may be hermetically sealed, and when the temperature rises to 60° F. the liquefied gas exerts a pressure of more than $2\frac{1}{2}$ atmospheres, viz., 2.54.

The liquid gas cooled below -105° F. freezes to a crystalline solid.

Sulphurous anhydride combines with water, and is then termed sulphurous acid, H_2SO_3 . Water dissolves 68.8 times its bulk of sulphurous anhydride at a temperature of 32° F. The solution is used now for certain throat diseases in the form of fine spray, and is a great boon to public singers or speakers,

and in some cases the cure effected is almost magical in rapidity. The acid is a powerful antiseptic and anti-putrescent body. It stops the ordinary fermentation of sugar, and is one of the best disinfectants that can be used. Sulphur burnt in the air will afford sulphurous anhydride sufficiently good for this purpose. Unlike chlorine, it is used as a deoxidizing agent for bleaching silk, flannel, isinglass, feathers, sponge, straw, &c. Sulphurous anhydride is not an inflammable gas, and will not support the combustion of a burning taper.

Sulphuric acid (dihydric sulphate, $\text{H}_2\text{SO}_4=98$) is the most important acid used in commercial chemical processes. One hundred thousand tons are made and used annually in this country.

The chief importance of the gas already considered, viz., sulphurous anhydride, is due to the fact that it is the starting-point in the manufacture of oil of vitriol. The gas, by a most ingenious process, is made to combine with half as much oxygen again as it already contained; and, what is still cleverer, the oxygen is obtained for nothing, because it is taken from the great reservoir of oxygen, viz., the air. Sulphurous anhydride and oxygen, both dry, when passed over spongy platinum heated in a tube, combine, and sulphuric anhydride (SO_3) is produced. It is called by some authors sulphuric trioxide. Curious to state, this body does not redden litmus or blacken the skin. It combines with water with great rapidity, and, when brought in contact with the latter fluid, hisses like a red-hot iron, forming sulphuric acid, H_2SO_4 .

In the commercial process sulphurous anhydride (SO_2) is oxidized in a capacious leaden chamber by the intervention of another gas (nitric oxide), with the assistance of moist air. Nitric oxide in contact with the air produces the red fumes of nitric trioxide (N_2O_3) which yields oxygen to the sulphurous anhydride, and converts it into sulphuric acid. The decomposition is thus tersely described by Roscoe:

$\text{SO}_2 + \text{H}_2\text{O} + \text{N}_2\text{O}_3 = \text{H}_2\text{SO}_4 + \text{N}_2\text{O}_2$ —sulphuric dioxide, water, and nitric trioxide—yield sulphuric acid and nitric oxide. The nitric oxide formed in this decomposition takes up another atom of oxygen *from the air*, becoming N_2O_3 , and this is again able to convert a second molecule of SO_2 with H_2O into H_2SO_4 , being a second time reduced to N_2O_2 , and ready again to take up another atom of oxygen *from the air*. Hence it is clear that N_2O_2 acts simply as a carrier of oxygen between the air and SO_2 ; an indefinitely small quantity of this nitric trioxide being, therefore, theoretically able to convert an indefinitely large quantity of sulphurous dioxide, water, and oxygen into sulphuric acid."

Protohydrate of sulphuric acid (the oil of vitriol of commerce), H_2SO_4 , is a dense oily-looking fluid, having a specific gravity of 1.842. It blackens organic matter, and when mixed with water becomes very hot: the volume of acid and water is found to be reduced in bulk when cold.

Sulphuric acid boils at a temperature of 620°F. , emitting a dense white vapour, and it distils without decomposition. Some pieces of platinum foil should be placed in the bottom of a distilling vessel to prevent the violent and explosive formation of the acid vapour.

If a little sulphuric acid is placed in a beaker up to a certain mark, it will be found in the course of a day or so to have risen above the mark, in consequence of the absorption of the watery vapour contained in the air. Organic substance, and especially sugar, is completely decomposed and charred when oil of vitriol is poured upon it. This acid has little or no action on metals in

the cold state, but when some of the latter are boiled in sulphuric acid, sulphates are obtained.

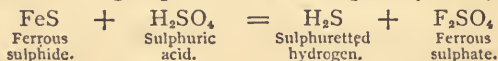
In the practice of the art of photography (see p. 574), large quantities of sodium hyposulphate are used. The latter salt is obtained by passing a current of sulphuric dioxide into a solution of sodium sulphide; the resulting hyposulphide is purified by crystallization. Hyposulphurous acid, or dithionous acid ($\text{H}_2\text{S}_2\text{H}_2\text{O}_4 = 132$), forms with sodium a salt in which one of the molecules of hydrogen is replaced by that of sodium, viz., $\text{Na}_2\text{H}_2\text{S}_2\text{O}_4$. A solution of this salt possesses the property of dissolving out the silver compound (iodide or chloride, as the case may be) which remains unaltered by light; whilst those portions of the silver compounds reduced to the metallic state by the action of light are not affected by this salt, which is therefore said to fix the photographic picture. Hyposulphurous acid is only known in combination, and has not yet been isolated.

COMPOUNDS OF SULPHUR WITH HYDROGEN.

Hydrosulphuric acid; sulphuretted hydrogen; dihydric sulphide, $\text{H}_2\text{S} = 34$. This gas was discovered by Scheele in the year 1774, and it is usually obtained from ferrous sulphide (FeS) by the action of dilute sulphuric acid.

To prepare the ferrous sulphide, some clean iron turnings or small coils of iron wire are to be placed in a covered crucible banked up with hot coke on the stage of the forge bellows (p. 62). The blast should then be urged until the crucible has attained a bright red heat, when the cover of the crucible may be raised, and fragments of sulphur dropped in. The action is very apparent, as the iron glows with a still more intense heat in the act of combining with the sulphur, and if the operation is nicely performed, the whole assumes the liquid state, and may be poured into a mould or allowed to cool in the crucible.

Ferrous sulphide, by decomposition with sulphuric acid, yields sulphuretted hydrogen; the iron being displaced from the sulphur by the hydrogen.



The sulphide of iron is placed in the bottle A, and sufficient water is poured upon it through the funnel B. A little sulphuric acid is now added, and the gas passes through the tube C, connected with E by a piece of vulcanized india-rubber tube. Here the gas is absorbed by distilled water in F, and if required pure, again escapes, when the latter is saturated through G by H and J into the beaker glass, K, containing more distilled water, or any fluid, such as a solution of lead or arsenic, whose presence it may be desirable to determine.

Water at 59°F . dissolves 3.23 times its bulk of sulphuretted hydrogen. The solution has a slight acid reaction, and, of course, the smell of the gas, which reminds the nose of the odour of putrid eggs. This gas, which consists of two volumes of hydrogen and one

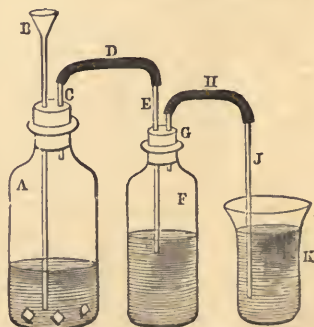


FIG. 39.—Preparation of Sulphuretted Hydrogen.

volume of sulphur vapour condensed into two volumes, has a specific gravity of 1.191; and 100 cubic in. weigh, at 60° F. and 30 in. bar., 38 grains. It is very poisonous, and if one measure is mixed with 600 or 1,200 measures of air, the highly diluted gas is still most poisonous and will soon cause the death of a mouse or a bird.

The analytical chemist requires this gas for the purpose of determining in a qualitative analysis the particular group to which any metal discoverable by this gas may be referred, and it is one of the most useful re-agents employed in the laboratory.

There is another compound of sulphur and hydrogen called hydric persulphide, or persulphide of hydrogen, H_2S_2 .

Sulphur also unites with carbon, forming a most useful and volatile fluid called carbonic bisulphide or bisulphide of carbon, $CS_2=76$. This compound dissolves phosphorus in the ordinary state, but not when in the amorphous condition. It is one of the best solvents of caoutchouc, gums, sulphur, &c.

Sulphur chloride ($S_2Cl_2=135$), sulphur dichloride ($SCl_2=103$), and nitrogen sulphide (SN) complete the list of sulphur compounds.

PHOSPHORUS.

Symbol, P. Atomic weight, 31.

A merchant of Hamburgh, engaged in the useless attempt to obtain the Philosopher's Stone exactly 200 years ago, viz., in the year 1669, discovered accidentally this peculiar substance. The name of this clever and persevering chemist was Brandt, who described the phosphorus he obtained as a "dark, unctuous, daubing mass." There are many other interesting particulars respecting the history of the discovery of this substance that will be found in a most exhaustive pamphlet by Mr. George Gore,* from which the following is taken:

"In a 'Historical Sketch of the Progress of Pharmacy in Great Britain, by Jacob Bell,' it is stated, that 'A house and shop, with a laboratory, were built on the Bedford estate, in the year 1706, by Ambrose Godfrey Hanckwitz, who had carried on business as a chemist in the neighbourhood since 1680. He was a maker of phosphorus and other chemicals, which were rare at that period, and which he sold in different parts of the country during his travels. His laboratory was a fashionable resort in the afternoon on certain occasions, when he performed popular experiments for the amusement of his friends. It opened with glass doors into a garden, which extended as far as the Strand, but which is now built upon. Four curious old prints of the laboratory in its former state are in the possession of its present proprietors, Messrs. Godfrey and Cooke, of Southampton Street, Covent Garden, also a portrait of Ambrose Godfrey Hanckwitz, engraved by George Vertue (1718), which he had distributed among his customers as a keepsake.'

"When we consider that 1,000 parts of urine contain scarcely one part of phosphorus, and of this probably only a portion was obtainable by the processes first in use, we shall not be surprised at the statement of Boyle that 'the liquor yields but a small proportion of the desired quintessence,' or at the price of 50s.

* "On the Origin and Progress of the Phosphorus and Match Manufactures." By G. Gore.

an ounce charged by Hanckwitz for his product. Even an improved process, purchased and published by the French Government in 1737, yielded, under the direction of Hellot, Geoffroi, Dufay, and Duhamel, only four ounces of phosphorus for every five hogsheads of the liquid.

After the death of Hanckwitz, in 1741, some experiments were made by Margraaf, Fourcroy, Vauquelin, and others; but no great improvement in the production of phosphorus appears to have been effected until 1769, when Gahn made the important discovery of phosphoric acid in bones. Margraaf had already demonstrated the individuality of this acid as early as the year 1740, and it only now remained to devise a process for extracting it. Scheele immediately did this, and various eminent chemists quickly succeeded in making various improvements in the method of working, and bequeathed unto us substantially the same process of manufacture as that now in operation.

"The present sources of phosphorus are the bones of buffaloes and other animals, slaughtered in the great hunting-grounds of South America (the Pampas bordering the La Plata), where bones are used as fuel; exhausted 'bone-black,' or 'animal charcoal' of sugar refineries; calcareous deposits of phosphate of lime, or 'mineral guano' from the coast of Yucatan; and similar deposits from the island of Sombremos; but the chief of these sources is the burnt bones from Monte Video, Rio Janeiro, Rio Grande, &c., and the animal charcoal of the sugar refineries. These various substances contain from 60 to 90 per cent. of their weight of phosphate of lime, or from 12 to 18 per cent. of phosphorus.

"The phosphorus-yielding material, of whatever kind, having been suitably ground, a weighed quantity of the powder is placed in a large circular tub, lined with lead, with a mixture of oil of vitriol and water, and stirred by means of a revolving wooden stirrer, driven by a steam-engine, steam being admitted by a pipe into the mixture to facilitate the action of the sulphuric acid upon the powder.

"The changes which bone-ash or other varieties of phosphate of lime undergo in the above operation are these: the oil of vitriol or sulphuric acid gradually unites with the lime and forms sulphate of lime, and sets the phosphoric acid free; so that after the process there remains a semi-fluid mixture of a solid substance, sulphate of lime (gypsum or plaster of Paris), with a fluid body, phosphoric acid, separable by filtration.

"The creamy mixture is now transferred, by means of ladles, to a filter or drainer, from which, with the aid of occasional stirring, the phosphoric acid filters into a vessel beneath. Water is added to the drained contents of the filter until the drainings cease to taste acid. The sulphate of lime or gypsum is then removed in its damp state, to a furnace or other source of heat, and dried, and constitutes a residuary product suitable for the manufacture of artificial manures.

"The dilute filtered solution of phosphoric acid, containing some phosphate of lime and a small quantity of sulphate of lime dissolved in it, is transferred to leaden vessels and slowly evaporated over a gentle fire; the small quantity of gypsum then deposits itself upon the bottoms of these vessels, and is removed by scraping. The liquid is deprived of as much more of its water as possible by further evaporation in similar vessels, and on cooling acquires the consistency of cocoa-nut butter.

"The butter-like paste is then well mixed with a due proportion of powdered charcoal, and the mixture heated in furnaces of brick or iron until it is brought

into as dry a powder as can be attained. The powder consists of charcoal, phosphoric acid (a compound of phosphorus and oxygen), a little phosphate of lime, and a little water, which is chemically combined with the phosphoric acid, and not capable of removal by the means yet applied.

"We have already alluded to the intense heat employed by Boyle and Hanckwitz in their distillation of phosphorus: the same is also necessary in the present mode of manufacture. The vessels in which the phosphorus is separated consist of a number (about ten) of small retorts, of a convenient shape, carefully constructed of the most refractory fire-clay, narrowed at their mouths, and arranged nearly close together in a horizontal row in a furnace, somewhat similar to the retorts in a gas-works. They are placed in a nearly horizontal position, with their open ends slightly raised, and in a furnace so constructed as to subject them to nearly a white heat.

"The black powder is introduced into the retorts when the latter are comparatively cool, and the retorts are about half filled with the mixture. Bent pipes, open at both ends, are inserted, air-tight by means of clay, into the mouths of the retorts, and their outer ends dip into warm water, in cast-iron basins, placed to receive the distilled phosphorus. I may now incidentally remark that all the manipulations with ordinary phosphorus in its simple and separated state are performed under the surface of water, otherwise it would quickly inflame and be reconverted into phosphoric acid.

"The heat of the furnace is gradually raised, and in the course of some hours phosphorus begins to distil over, and accumulates in a melted state in the basins of water. The fire is still further raised, by gradual means, until a most intense heat is obtained; the phosphorus then distills rapidly. The heat, after being thus continued as long as any more phosphorus appears, is gradually decreased, and the basins containing the crude phosphorus are removed. The time occupied in the distillation is, in some cases, protracted from forty-eight to seventy-two hours.

"In this operation the charcoal, at a high temperature, combines with the oxygen of the phosphoric acid, forming therewith carbonic oxide and carbonic acid gases, which escape through the nose-pipe, and the phosphorus thus set free is converted into vapour by the heat, and distills over into the receiving-basins. At the same time, the portion of water not extracted by the preceding process is also decomposed, and, its hydrogen set free, combines with some of the phosphorus and forms phosphuretted hydrogen gas. The inflammable gases, carbonic oxide and phosphuretted hydrogen, are conducted away from the phosphorus basins by means of a pipe, and consumed.

"When the distillation is at an end, the furnace is cooled down and the residuary contents of the retorts extracted. The residue consists chiefly of charcoal (of which there is always an excess) and of undecomposed phosphate of lime, together with a few impurities, and is used in the composition of manures, the phosphorus in it being of too difficult or too unprofitable extraction. From the penetrating and destructive character of phosphorus, the retorts require frequent renewing, some manufacturers; when the best fire-clay is not employed, not using them for more than one operation.

"The appearance of a phosphorus distillery containing between 200 and 300 retorts, which we have frequently visited when in full operation and the furnaces at their maximum heat, is somewhat fearful: the long, yellow flames of phosphuretted hydrogen and carbonic oxide shooting forth from the escape-pipes; bits of burning phosphorus spitting forth in fiery balls from little crevices or

leaks at the mouths of the retorts; the incessant bubbling of the vapour of phosphorus and escaping gases in the basins of hot water; the almost unbearable heat from the furnaces on each side, and from the red-hot flues under foot; the intolerable stench of phosphuretted hydrogen and burning phosphorus; together with the acid fumes and filthy grim aspect of the place, combined to produce an impression on our senses which we cannot fail to remember.

"The small cakes of crude phosphorus, each weighing several pounds, are collected from the iron receiving-basins when cold, and melted together under water. The impurities which were carried over from the retorts into the basins by the current of gases and phosphorus vapour, now settle to the bottom of the fluid mass, and the supernatant phosphorus is drawn over into shallow copper pans, containing a small quantity of hot water to prevent contact of air, by means of leaden syphons previously filled with hot water, and allowed to solidify.

"The large cakes or cheeses of phosphorus thus obtained still contain impurities, and are of a dirty red colour, chiefly arising from the mechanical admixture of a red variety of phosphorus in small particles. They are broken to pieces under cold water, and the fragments placed in hot water contained in a leaden vessel (heated by steam), together with a bleaching agent. The phosphorus is stirred with the heated mixture until it is bleached, or its brownish colour is removed, which generally occupies two or three hours.

"The liquid phosphorus is again drawn by means of syphons into shallow copper pans, and allowed to solidify. It is then broken under water, and the pieces are placed in hot water in a double-sided (or steam-jacketed) vertical iron cylinder, lined with lead, with a perforated bottom covered with chamois leather and canvas; and while in the fluid state pressure is applied to the phosphorus, and it passes through the leather, &c., into a vessel of hot water beneath, leaving the residuary impurities, red phosphorus, &c., upon the cloth in the form of a dirty reddish substance of an earthy appearance.

"The bleached and purified phosphorus is now cast into wedge-shaped pieces, or it is moulded into cylindrical sticks, half an inch in diameter, and 10 in. long, by the aid of glass tubes immersed into the phosphorus under water, or by means of an apparatus with tubes specially contrived for the purpose. On some occasions the phosphorus is very brittle and difficult to draw into sticks, but if it is in a satisfactorily pure state it is as ductile as lead or soft copper wire. The appearance of the purified phosphorus in the form of wedges is that of very transparent wax or glass of a slightly greenish-yellow colour, but when in the form of sticks it usually appears colourless. It is needful on all occasions to protect the purified substance from strong daylight, otherwise it soon becomes yellow and opaque. For conveyance it is always packed in water, generally in tin cans, the covers of which are soldered air-tight.

"The phosphorus we have described is that of the ordinary kind; but there is another variety, equally pure, discovered in 1848 by Professor Schrötter, of Vienna, which is produced as follows: The ordinary phosphorus in its purified state is placed under water in a cast-iron boiler over a furnace; then melted, cooled, and the water removed from its surface. The vessel is then immediately and securely closed, air-tight (except a small iron tube for the escape of vapour), by a cast-iron cover. The lid has a vertical iron tube, closed at its lower end, fixed in it, which projects downwards into the phosphorus, and is open at its

upper end for the reception of a thermometer. Heat is now gradually applied by means of the furnace until the phosphorus is at about 450° F., and that temperature is maintained for a greater or less period of time, according to the amount of phosphorus operated upon, and the mass is then allowed to cool. A quantity of about 200 pounds is kept heated about three or four weeks. After this process the vessel is opened, and the phosphorus, which has now become a hard, red brick-like substance, is covered with water, and extracted by means of iron bars, &c. This process of conversion requires to be conducted with great circumspection, otherwise (from overheating of the phosphorus) fearful explosions may ensue; experience has, however, shown that they may be almost wholly avoided.

"For commercial purposes the red or amorphous phosphorus, as it is termed, is required to be in a state of fine powder; the stony fragments are, therefore, broken into small pieces under water in a mortar, and ground under water between pieces of mill-stone in a vessel supplied with a small stream of water, which carries off the finer particles in its overflow stream into a large tank, where they gradually subside, or into a filter where they are collected. A process is then resorted to for the separation of any ordinary phosphorus which the powder may contain.

"This wet and finely-divided substance having been dried, sifted, and packed in air-tight tins, is ready for sale.

"It is well known in modern chemistry that a substance may exist in two or more physical states, possessing very different physical and chemical properties, and that there may be as great a difference in the properties of the same substance in its different states of aggregation as there is between two chemically different substances. For instance, there is as great an amount of physical difference between carbon as it exists in the diamond and as it exists in pure lamp-black as between copper and silver or silver and gold. The two kinds of phosphorus we have described are, then, precisely the same chemical substance, but in different states of aggregation. The following is a comparison of their properties. We will, for convenience, term them white and red phosphorus:

WHITE.	RED.
Poisonous.	Innocuous.
Evolves a strong odour.	Nearly odourless.
Phosphorescent—luminous in the dark.	{ Not phosphorescent—perfectly illu- minous.
Melts at 108° F.	Melts at above 500° F.
Very transparent.	Opaque.
Almost colourless.	{ Varies in colour from nearly black (with metallic lustre) to iron-grey, brick-red, crimson, and scarlet.
Freely soluble in various liquids.	Nearly insoluble in all liquids.
Distinctly crystalline.	{ Destitute of all crystalline structure (amorphous).
Soft, may be indented by the nail.	Hard as a common red brick.
Flexible as copper or lead.	Brittle as glass.

"The great and most conspicuous fact is that red phosphorus may be kept in the dry state, exposed to the air, without inflaming; whilst the ordinary variety, under the same circumstances, quickly ignites. The minutest quantity

of ordinary phosphorus in the red or amorphous variety can be detected by digesting the latter, in the state of powder, in bisulphide of carbon, and then letting fall a single drop of the clear liquid upon a saucer floating upon boiling water in a dark place; luminosity will immediately appear if white phosphorus is present.

"There are several uses to which phosphorus has been applied; but, as far as quantity is concerned, almost the only important application is in the manufacture of lucifer matches. It is remarkable that, although the property of phosphorus of igniting by friction was known soon after its discovery, it was not until about the year 1833 that it was successfully applied to the manufacture of matches. It was then sold wholesale at four guineas a pound; in 1837, at two guineas; and at the present time, at less than 2s. 6d. Manufactories of it exist in Great Britain, France (Lyons), Bavaria, Baden, Austria, and Sardinia.

"Since the commencement of the manufacture of phosphorus upon a large scale in England, in 1845, the value of phosphorus imported into this country has regularly and rapidly decreased. According to the reports of the Great Exhibition of 1851, the value of phosphorus imported from all parts into Great Britain in 1844 was £2,567, and in 1850 only £3. And since that period it has become an article of constant export to the Continent and other parts, the proportion consumed in the United Kingdom being comparatively small. In his 'Catechism of Agricultural Chemistry,' Professor Johnston states that 200,000 lbs. of phosphorus are consumed in London alone per annum. Persons conversant with the actual consumption know that at that time, and probably at the present hour, it would not exceed 20,000 lbs.

"It is also stated in a recent publication on Chemistry, by Professor Muspratt (article 'Phosphorus,' p. 680), that phosphorus 'is prepared as an article of manufacture in large quantities in London and Paris. Kane has calculated that in the latter city alone about 200,000 lbs. are yearly produced.' There may have been once a very small production in London and Paris, but it has long since entirely ceased. The enormous consumption of fuel necessitates that, for an economic production, the manufactory be placed where coal is cheaply obtained; and the quantity of phosphorus produced in all France, at the date of Dr. Kane's book, is not likely to have been at all more than 20,000 lbs. It is plain that, by mistake, a cypher too many has been added."

RED PHOSPHORUS.

Dr. Muspratt describes the following process for preparing this form of phosphorus, which is effected in the apparatus shown in Fig. 40. A quantity of common dried phosphorus is placed in the flask A, to the neck of which a long narrow tube, *b*, bent downwards, is attached, the open end of which dips into a little mercury. The removal of the air is accomplished by means of a current of carbonic acid evolved from the bottle E, containing marble and hydrochloric acid. The gas is dried by passing it over chloride of calcium contained in the tube F. The flask being emptied of air, the tube is closed by fusion at the narrow portion, *a*, and the apparatus evolving carbonic acid removed. The flask is then heated by means of an oil bath, *c*; the phosphorus melts readily, and by regulating the heat steadily between 450° and 460° by means of a thermometer, *d*, and maintaining it thirty or forty hours, nearly the whole will be converted into the solid amorphous variety. When the meta-

morphosis appears to be complete, the apparatus is allowed to cool. Any unaltered phosphorus is separated by digestion in bisulphide of carbon, in which amorphous phosphorus is insoluble. The latter is afterwards collected in a filter and washed with bisulphide of carbon, as long as anything is removed from it, which may be ascertained by evaporating a small portion in a watch-glass, when any dissolved phosphorus will remain behind.

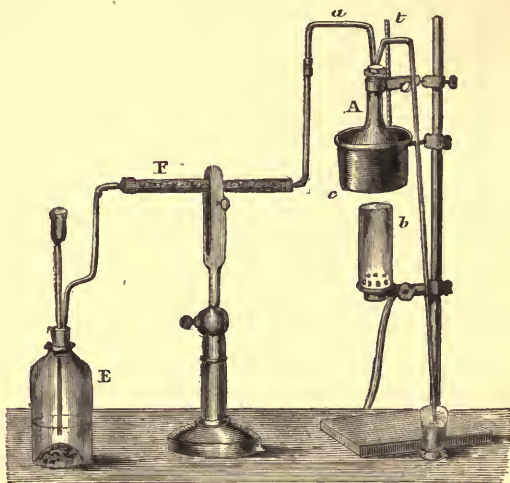


FIG. 40.

Crystals of phosphorus having a bright metallic lustre and a specific gravity of 2.34—nearly double that of ordinary phosphorus, which has a specific gravity of 1.83—may be obtained by dissolving amorphous or red phosphorus in melted lead. Amorphous phosphorus has a specific gravity of 2.14.

There are two oxides of phosphorus which are anhydrous, viz.—

Phosphoric trioxide (phosphorus anhydride), P_2O_3 ;

Phosphoric pentoxide (phosphoric anhydride), P_2O_5 ;

The latter represents the dense white smoke that passes off when phosphorus is burnt in a cup, so that the air does not have free access to it; or if phosphorus is burnt under a bell-jar in dry air, a quantity of a snow-white flocculent non-crystalline substance collects on the sides of the glass, or falls chiefly to the lower part if the glass is standing on a marble disc. This substance is phosphoric pentoxide, and, like sulphuric trioxide, hisses like a red-hot iron when brought in contact with water. The equation is $P_2O_5 + 3H_2O$, the phosphoric pentoxide having united with three molecules of water to form $2H_3PO_4$, two molecules of tribasic phosphoric acid. There are two other acids of phosphorus,—dibasic and monobasic; the hydrogen being the base, as already explained, that determines the rank of the acid.

- | | |
|---|------------------------------------|
| 1. Monobasic hypophosphorous acid . . . | $\text{H}_2\text{P}_2\text{O}_4$; |
| 2. Dibasic phosphorous acid . . . | $\text{H}_2\text{P}_2\text{O}_3$; |
| 3. Tribasic phosphoric acid . . . | H_3PO_4 . |

As there are three allotropic conditions of phosphorus, so there are three varieties of phosphoric acid—in fact, different acids:

Tribasic phosphoric acid, H_3PO_4 ;
 Pyrophosphoric acid, $\text{H}_4\text{P}_2\text{O}_7$;
 Metaphosphoric acid, HPO_3 .

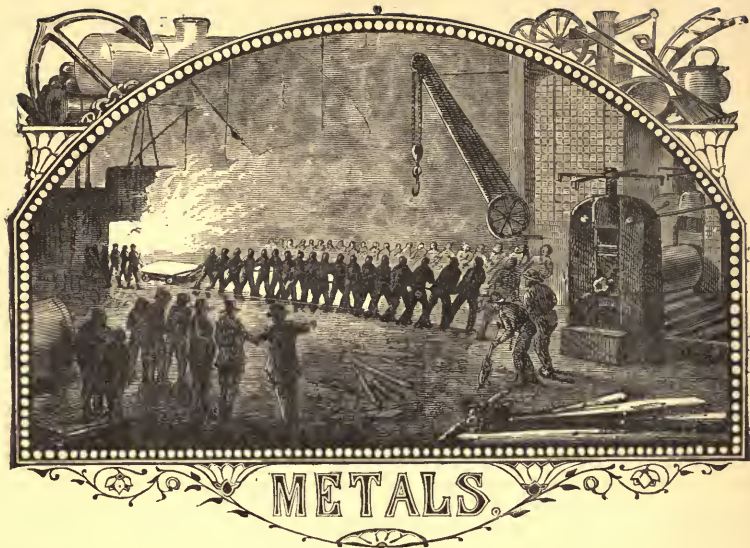
Each of these acids forms its own peculiar metallic salts.

Tri-sodium phosphate (Na_3PO_4) dissolved in water precipitates from argentic nitrate a *yellow* precipitate of triargentic phosphate (Ag_3PO_4). Sodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7$) with the same silver salt forms a *white* precipitate, consisting of $\text{Ag}_4\text{P}_2\text{O}_7$. Sodium metaphosphate (NaPO_3) forms with the same silver salt—argentic nitrate—a gelatinous white precipitate (AgPO_3) quite different from the other two.

There are three compounds of phosphorus and hydrogen. One is a solid, and called solid phosphide of hydrogen (HP_2); the second is a liquid, termed liquid phosphide of hydrogen (H_2P); and the third a gas, phosphuretted hydrogen (H_3P). The last-named compound has the peculiar property of taking fire spontaneously when brought in contact with the air, and is generally prepared by placing some phosphorus in a retort, and then filling the latter, neck and body, with a solution of caustic potash. By boiling the solution of potash this gas is eliminated, and, when it has filled the upper part of the retort and driven the fluid out of the neck, every bubble that escapes takes fire spontaneously, forming a beautiful ring of white smoke. Of course the neck of the retort must be kept under water, and if it is allowed to dip into a small basin containing more solution of potash, the retort and its contents may be used for several days to show the evolution of phosphuretted hydrogen; because, when the retort is allowed to cool, solution of potash fills the void that is created, and if air entered instead of the solution, an explosion would most likely occur that might burst the retort.

There are chlorides, bromides, and iodides of phosphorus, and a phosphide of nitrogen called phosphane by Gerhardt, who has laboured so industriously to reform chemical nomenclature.

Sulphur and phosphorus unite, forming compounds, in two of which the molecules unite in the same relative proportions as phosphorus anhydride (P_2O_5) and phosphoric anhydride (P_2O_3), the corresponding sulphur compounds being P_2S_5 and P_2S_3 .



THE METALS.

TELLURIUM.

Symbol, Te. Atomic weight, 129. Specific gravity, 6.25.

Henry Watts, in his "Dictionary of Chemistry," agrees with other scientific writers in stating that "this element, though decidedly metallic, must be classed as a member of the sulphur family, as it approximates very closely in its chemical character to sulphur, and still more to selenium. It was first identified as a distinct metal by Klaproth in 1798, who gave it the name 'tellurium,' from Tellus, the mythological name of the earth. Tellurium is one of the rarer metals, being found in a few localities only, and chiefly in Hungary and Transylvania."

"Tellurium in its chemical relations bears a very close analogy to sulphur and selenium. It forms two oxides—tellurous oxide (TeO_2) and telluric oxide (TeO_3)—which, in combination with water and with metallic bases, yield acids and salts analogous to those formed by the corresponding oxides of sulphur and selenium."

Tellurium crystallizes, and has a bright tin-like metallic lustre; it melts at about 800 or 900° F., and at a high temperature is converted into a yellow vapour. It burns when strongly ignited in air, with a blue flame edged with green, emitting a peculiar odorous vapour. Swallowed in minute quantities, it imparts to the breath a strong garlic flavour.

Telluretted hydrogen (H_2Te) is a gaseous body very like sulphuretted hydrogen; in fact, its odour is almost identical with that of the latter.

Tellurium is a bad conductor of electricity and heat, and is thus early spoken of because of its analogy to the non-metallic bodies sulphur and selenium.

ARSENIC.

Symbol, As. Atomic weight, 75. Specific gravity, 5.70 to 5.95.

The consideration of this metal is entered upon here because, like tellurium, it has certain chemical characteristics which place it closely in analogy with non-metallic elements, viz., phosphorus and nitrogen; at the same time it has other physical qualities that bring it in close proximity to the two metals antimony and bismuth.

Arsenic may be regarded as an intermediate link between the non-metallic bodies already considered and the metallic elements which have next to engage our attention. In the brief summary of each metal, its sources, and its physical and chemical properties, will be considered.

SOURCES OF ARSENIC.

The greater part of the arsenical pyrites (mispickel, FeAsS), from which the white oxide of arsenic is procured, is found in Bohemia, Norway, Sweden, Hungary, Saxony, and other places on the Continent. Arsenic occurs as an alloy with tin, copper, cobalt, and nickel; also united with oxygen and certain metals, as in the arseniates of copper, lead, and iron.

There are natural sulphides of arsenic, viz., the red sulphide, called realgar, and the yellow, termed orpiment.

Arsenic is occasionally found in the native state, and is one of the most widely diffused natural bodies, being sometimes contained even in mineral springs.

White arsenic, arsenious oxide, or trioxide of arsenic (As_2O_3) is obtained by roasting the sulphide of iron, or other minerals containing arsenic, in a reverberatory furnace connected with a long chimney, which is nearly horizontal, but terminating in a tower of brickwork also divided into compartments, so that all the volatile products shall be condensed during the slow passage of the current from the reverberatory furnace.

The crude arsenious oxide is purified by sublimation, and, being heated in a retort with charcoal, is reduced to metallic arsenic, which sublimes into the receiver.

PHYSICAL QUALITIES OF ARSENIC.

The metallic nature of arsenic was discovered by Brandt in 1733. It is of a steel-grey colour, easily tarnishing in air, but retaining its brilliant aspect under water, especially if the latter is first boiled and placed with the arsenic in an air-tight bottle. It is very brittle, and easily pounded in a mortar.

Arsenic has no smell when cold, and, if heated, does not melt, but sublimes easily, and then emits a strong odour resembling garlic. Tubes for experiments with arsenic may be obtained from Mr. How, of Foster Lane, Cheap-side. A certain quantity of the metallic arsenic is usually oxidized in the presence of air. It is a most violent poison, and hence derives its

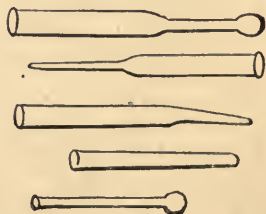


FIG. 41.—Tubes for experimenting with Arsenic.

name from *αρσενικον* (powerful), on account of the small quantity sufficient to cause death.

CHEMICAL PROPERTIES OF ARSENIC.

Arsenic combines with the metals like sulphur or phosphorus, and, when heated in the air, ignites, burning with a bluish flame and forming arsenious oxide. It takes fire immediately when powdered and dropped into chlorine gas, forming arsenic trichloride (AsCl_3). There are two oxides of arsenic: the sesquioxide or arsenious anhydride, arsenious acid, arsenic trioxide (As_2O_3), and arsenic anhydride, arsenic pentoxide, or arsenic oxide (As_2O_5). The preparation of the first-named compound has already been described; the second, arsenic pentoxide, is obtained by digesting white arsenic with nitric acid, and then boiling down the solution in a platinum or hard porcelain vessel.

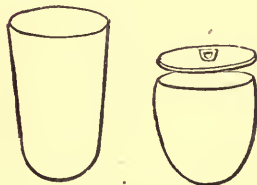


FIG. 42.

Hard Porcelain Cups and Crucibles for analytical purposes.

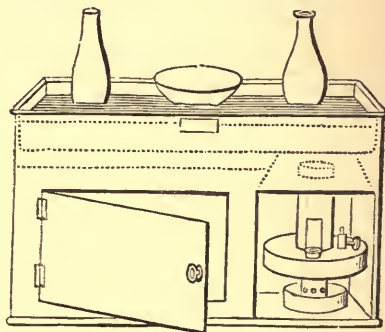


FIG. 43.—*Portable Sand Bath and Oven, heated by an Oil Lamp.*

In the absence of a supply of coal-gas, and especially where operators amuse themselves in the country with chemical experiments, a steady moderate heat is often required for the solution of various minerals and metals in acids or other solvents; this is conveniently obtained with a sand bath heated by a common Argand oil lamp, which is so arranged that the heat shall be economized, and whilst imparting it to the sand above, a small oven is also warmed, in which precipitates or filters may be easily dried.

Arsenic is employed for various purposes: it is used in the manufacture of small leaden shot; it enters into the composition of the alloys of tin and copper used in making metallic specula for telescopes. In fluxing certain kinds of glass, and oxidizing the ferrous oxide to get rid of the green tinge, it is found to be very useful.

There are many pigments which owe their brilliancy to the presence of this metal, as "Scheele's green," or hydrocupric arsenic (CaHAsO_3), or Schweinfurt green, a cupric arsenite and acetate ($3\text{CaAs}_2\text{O}_5, \text{Ca}_2\text{C}_2\text{H}_3\text{O}_2$).

Arsenic is employed to prevent smut in grain and in poisoning vermin, and being such a terrible poison easily obtainable, it is not surprising that poor

ignorant criminals should use it for destroying human life, always forgetting that, although so readily procured, it is still more easily detected.

The characteristic results obtained by using the proper reagents or tests for arsenic are unmistakable.

The testing operations for arsenic may be conducted on the smallest possible scale, and yet are most conclusive, and for this purpose plenty of clean dry test tubes should be provided.

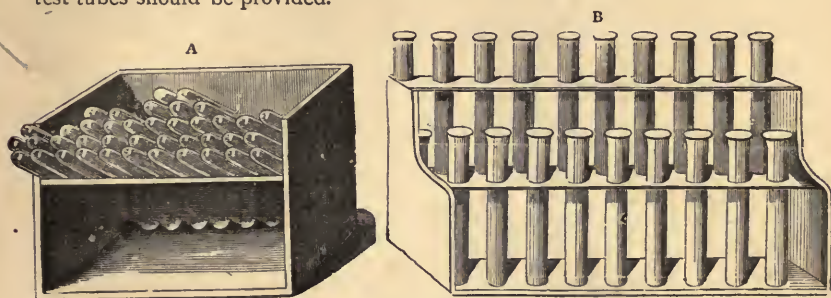


FIG. 44.

A, test tubes washed and draining, to be placed in rack B for use.

The identification of arsenic may be conducted with quantities so minute as to be inappreciable by the balance. The presence of arsenic in any mineral is readily detected by the skilful use of the blowpipe. A fragment of mispickel (FeAsS) is powdered, and heated with dry carbonate of soda and charcoal before the blowpipe, a well-trained nose soon detects the peculiar garlicky odour when the heat is applied.

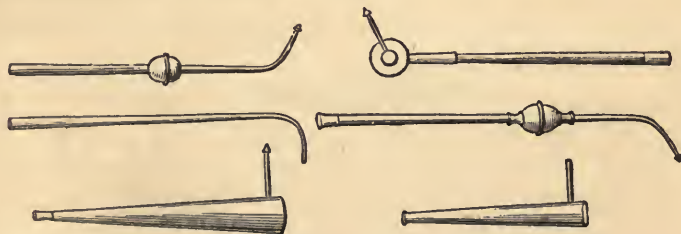


FIG. 45.—*Various Blowpipes used by Chemists and Mineralogists.*

The flame of a spirit lamp will answer for most of the blowpipe experiments, and when gas is laid on there is usually a jet attached to the mixed air and gas burner for this purpose. As an illustration of the convenience of the gas burners, Normandy's burner with blowpipe gas jet is shown in Fig. 46.

When in solution, the compounds of arsenic are detected by the following tests:

If the arsenic be in the condition of arsenious acid, and supposing the organic matters removed by processes all described in works on toxicology,

solution of nitrate of silver with a drop of ammonia causes a yellow precipitate of triargentic arseniate, freely soluble in excess of ammonia or in nitric acid. Sulphuretted hydrogen causes a yellow precipitate of arsenious sesquisulphide: this must be allowed to subside, and is then collected, dissolved in

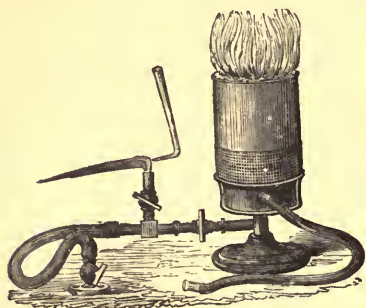


FIG. 46.—*Dr. Normandy's Burner, with independent Blowpipe Flame.*

ammonia, and evaporated to dryness on a water bath. The dry sesquisulphide is reduced to the metallic state by mixing it with some potassic cyanide and sodic carbonate, all well dried and mixed; and placing it into one of the tubes, Fig. 41, the mixture is now heated strongly by the blowpipe, and the metallic arsenic condenses in the upper part of the tube, giving to it the appearance of a brilliant mirror having a steel-grey aspect. Solution of sulphate of copper with a drop or so of ammonia throws down a green precipitate, hydrocupric arsenite or Scheele's green. A little solution of arsenious acid evaporated to dryness with nitric acid, and converted into arsenic acid, and then re-

dissolved with the addition of a drop of ammonia, gives the marked brick-red precipitate, when a solution of nitrate of silver is added. The brick-red precipitate is triargentic arseniate (Ag_3AsO_4).

Marsh's test is one of the most conclusive when the inquiry is made for judicial purposes. A bottle, A, fitted with a cork and small funnel, is charged with pure granulated zinc and water; to this is adapted a tube, B, containing calcic chloride, to stop any particles of fluid that might be carried over mechanically; to the last-named tube is attached a bulb, C, drawn out to a capillary



FIG. 47.—*Marsh's Test for Arsenic.*

tube, and made of hard German glass, and under which (when all the atmospheric air is driven out by the current of hydrogen formed by pouring pure sulphuric acid down the funnel attached to A) the flame of a spirit lamp is placed, at the point just where the capillary portion of the bulb tube commences. Ten minutes are allowed to ascertain if all the materials are pure, and that no deposit whatever takes place in the bulb. The solution supposed to contain the

arsenious acid is now poured down the funnel into A, and, if arsenic be present, arseniuretted hydrogen (H_3As) is formed, and decomposed as it passes through the heated tube, the metal being deposited like a ring of burnished steel just beyond the part where the heat is applied. Marsh's test, taken in conjunction with Reinsch's test and the others already described, affords evidence which is indisputable. The arseniuretted hydrogen, if allowed to escape through the cold bulb and inflamed at the aperture, burns with the peculiar flame of arsenic; and if a cold piece of porcelain be held against the flame, rings of metallic arsenic are deposited, distinguishable from antimony, which behaves in a similar manner, by the fact that antimonial stains disappear when a drop of ammonia sulphide in which a little sulphur is dissolved is added, whilst the arsenical crusts are hardly affected by the same re-agent.

ANTIMONY.

Symbol, Sb (Stibium). Atomic weight, 122.

It has already been mentioned that arsenic, antimony, and bismuth closely resemble phosphorus in their chemical, though not exactly in their physical, qualities; this group of three metals is therefore taken first, because it is the connecting-link between the non-metallic and metallic elements.

SOURCES WHENCE DERIVED.

Antimony, though sometimes found native, is chiefly derived from the ore or sesquisulphide (Sb_2S_3), which is found in Hungary, Norway, Saxony, and Sweden. This ore is first purified from the earthy matter: by exposure to a strong heat in a reverberatory furnace the ore melts and separates from the impurities, and is cast into cakes called crude antimony.

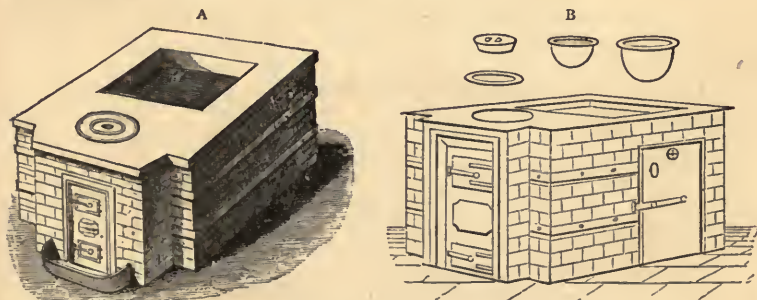


FIG. 48.—*Useful forms of Furnaces, with Sand Bath and Oven, And various-sized rings and iron pots for chemical purposes.*

If 4 parts of crude antimony, 3 of crude tartar, and $1\frac{1}{2}$ of nitre are thoroughly powdered and mixed, and thrown gradually into a Hessian crucible kept at a bright red heat, the ore is reduced to the metallic state. A furnace with a capacious and tall chimney can be built so that the whole draught is con-

nected with the fireplace, or diverted when required, by proper dampers, to a sand bath, as at A, Fig. 48, or it may heat an oven and sand bath, as at B, Fig. 48.

PHYSICAL PROPERTIES OF ANTIMONY.

This metal was discovered by Basil Valentine at the latter end of the fifteenth century, and is so called from the Greek *αντι*, against, and *μονος*, a monk, because it is stated that some monks were unfortunately poisoned by medicine prepared from this metal. Antimony is crystalline and has a brilliant silvery-white aspect, and, having very little tenacity or ductility, is therefore easily powdered. The specific gravity of this metal is 6.715, and it melts at about 1,150° F. It is used in forming various important alloys, such as type and britannia metals and pewter. The well-known medicine called James's Powder contains this metal and "tartar emetic," a true chemical compound of potassium, oxide of antimony, tartaric acid, and water is also extensively used in the healing art.

CHEMICAL PROPERTIES OF ANTIMONY.

Antimony retains its brilliancy when exposed to the air; but if melted rapidly it changes by combining with the oxygen of the air. If the heat is strongly urged it will burn with a white flame, forming a heavy white smoke—the antimonious trioxide. Powdered antimony takes fire when thrown into chlorine gas, and becomes very hot if brought in contact with iodine and bromine, with which it also unites. Aqua regia, nitro-hydrochloric acid, dissolves antimony freely; if nitric acid be used alone, the metal is converted into a straw-coloured insoluble antimonious oxide: boiling hydrochloric acid will dissolve it. Metallic antimony is also dissolved when digested in fine powder with a solution of one of the sulphides of potassium.

Antimony forms three oxides:

Antimonious oxide, Sb_2O_3 ;

Antimonic oxide or anhydride, Sb_2O_5 ;

Antimonious antimoniate, $\text{Sb}_2\text{O}_3\text{Sb}_2\text{O}_5$.

It is the first of these oxides which is used in medicine.

This metal-like arsenic unites with hydrogen, forming antimoniuiretted hydrogen, having the probable constitution of SbH_3 , and is evolved whenever the metal is brought in contact with zinc and dilute sulphuric acid.

There are many niceties required in the discrimination of this metal from arsenic; and as both metals are used by poisoners, the reader is referred to the best works on toxicology for the analytical processes required, not only to detect antimony, but also to distinguish it from arsenic.

BISMUTH.

Symbol, Bi. Atomic weight, 210.

SOURCES WHENCE DERIVED.

Bismuth, though not a rare metal, is by no means abundantly distributed throughout the crust of the earth. It occurs native in Saxony, Bohemia, and Transylvania, and is simply melted out of the crushed quartz with which it is

associated. It also occurs with cobalt in the cobaltic ores of Saxony and England. A sulphide of bismuth, called "bismuth glance" (Bi_2S_3), is another natural mineral containing this metal.

PHYSICAL PROPERTIES.

In some works bismuth is described as a yellowish-white metal, but it is in fact reddish-white: this apparent difference in the bloom or tint of the metal was observed by the discoverer Agricola in 1529, who called it "*Wiessmatte*," "a blooming meadow," on account of the variegated hues of its tarnish. It has a specific gravity of 9.799, reduced by Marchand and Scheerer (who, apparently, compressed the internal cavities in the specimen of bismuth they used) to 9.556. The metal is easily fusible, and melts at a temperature of 507°F . Bismuth, like antimony and arsenic, has little malleability, ductility, or tenacity, and is so brittle that it may be easily reduced to powder under the hammer.

On account of the singular property it possesses of *expanding* when cooling it is extremely valuable in testing the progress of a die, and is therefore constantly employed by die-sinkers, who, with type-makers, call it "tin glass."

CHEMICAL PROPERTIES.

Bismuth is slightly volatile when strongly heated, and, like arsenic, tarnishes in the air, but not so if kept in a well-stoppered bottle containing boiled distilled water. At a red heat bismuth quickly oxidizes, and also takes fire in chlorine when very finely powdered and dropped into that gas. Sulphur, bromine, and iodine all unite with this metal.

Bismuth is quickly dissolved by nitric acid, which is its proper solvent.

Two oxides of bismuth are known: bismuth oxide or sesquioxide of bismuth (Bi_2O_3), and an acid oxide or anhydride (Bi_2O_5).

The nitrate ($\text{Bi}_3\text{NO}_5 \cdot 5\text{H}_2\text{O}$) appears to be the best known and most important salt of bismuth. When the solution is largely diluted with water, an insoluble basic compound is formed, or sub-nitrate ($\text{Bi}_2\text{O}_3 \cdot 2\text{HNO}_3$). This precipitate, when collected and moderately washed and dried, is the well-known cosmetic, so freely prescribed by the improvers of complexions, called "pearl white." The old alchemical writers called it the "magistry of bismuth." For drying precipitates various convenient

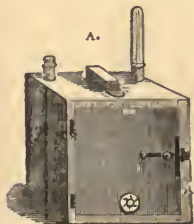
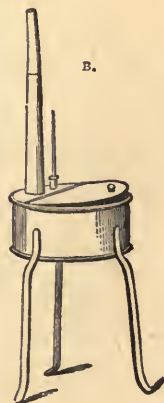


FIG. 49.

A, oven heated by boiling water; B, hot air oven, heated by gas, oil, or a spirit lamp.

ovens are made by Mr. How, of Foster Lane. When surrounded by water and the steam allowed to escape freely, the oven, of course, does not afford a heat higher than 212°F .

The hot air oven is heated from below with a gas-flame; a much higher temperature may be obtained, and conveniently regulated by a thermometer. No solder is used in the construction of these ovens, which are most useful for drying precipitates.

The general chemical analogy between nitrogen, phosphorus, arsenic, antimony, and bismuth is well shown by tabulating some of the compounds having the same number of combining molecules.

N_2O_3	.	.	.	.	Nitrous anhydride.
P_2O_3	.	.	.	.	Phosphorus do.
As_2O_3	.	.	.	.	Arsenious do.
Sb_2O_3	.	.	.	.	Antimonious do.
Bi_2O_3	.	.	.	.	Bismuthous do.

CLASSIFICATION OF THE METALS.

Although the metal tellurium, and the group of metals, arsenic, antimony, and bismuth, have been discussed because of their remarkable analogy to certain bodies belonging to the non-metallic substances, the arrangement of the whole of the metals in proper groups must not be omitted, because the student is so much assisted by studying them not only individually, but in their relations to each other.

Gmelin arranges the metals in six groups, Dr. Miller in eight, and Professor Roscoe in eleven classes, the latter of which will be adopted.

I. METALS OF THE ALKALIES (*five in number*).

- | | | |
|--------------|------------|--------------|
| 1. Potassium | 3. Lithium | 5. Rubidium |
| 2. Sodium | 4. Cæsium | (?) Ammonium |

II. METALS OF THE ALKALINE EARTHS (*three in number*).

- | | | |
|-----------|--------------|------------|
| 1. Barium | 2. Strontium | 3. Calcium |
|-----------|--------------|------------|

III. METALS OF THE EARTHS (*nine in number*).

- | | | |
|--------------|--------------|--------------|
| 1. Aluminium | 4. Erbium | 7. Lanthanum |
| 2. Glucinium | 5. Zirconium | 8. Didymium |
| 3. Yttrium | 6. Cerium | 9. Thorium |

IV. ZINC CLASS (*three in number*).

- | | | |
|--------------|---------|------------|
| 1. Magnesium | 2. Zinc | 3. Cadmium |
|--------------|---------|------------|

V. IRON CLASS (*seven in number*).

- | | | |
|-----------|-------------|--------------|
| 1. Cobalt | 3. Uranium. | 6. Manganese |
| 2. Nickel | 4. Iron | 7. Indium |
| | 5. Chromium | |

VI. TIN CLASS (*four in number*).

- | | | | |
|--------|-------------|------------|-------------|
| 1. Tin | 2. Titanium | 3. Niobium | 4. Tantalum |
|--------|-------------|------------|-------------|

VII. TUNGSTEN CLASS (*three in number*).

- | | | |
|---------------|-------------|-------------|
| 1. Molybdenum | 2. Vanadium | 3. Tungsten |
|---------------|-------------|-------------|

VIII. ARSENIC CLASS (*three in number*).

- | | | |
|------------|-------------|------------|
| 1. Arsenic | 2. Antimony | 3. Bismuth |
|------------|-------------|------------|

IX. LEAD CLASS (*two in number*).

- | | |
|---------|-------------|
| 1. Lead | 2. Thallium |
|---------|-------------|

X. SILVER CLASS (*three in number*).

- | | | |
|-----------|------------|-----------|
| 1. Copper | 2. Mercury | 3. Silver |
|-----------|------------|-----------|

XI. GOLD CLASS (*seven in number*).

- | | | |
|-------------|--------------|------------|
| 1. Gold | 3. Palladium | 6. Iridium |
| 2. Platinum | 4. Rhodium | 7. Osmium |
| | 5. Ruthenium | |

CLASS I.

POTASSIUM, SODIUM, RUBIDIUM, CÆSIUM, LITHIUM,
AMMONIUM.

Metals of the Alkalies.

POTASSIUM.

Symbol, K (Kalium). Atomic weight, 39.1.

Potassium monoxide (K_2O), united with water, forms potassium hydrate (HKO), commonly called *potash*, and gives the name to this metal, so called from the pots in which the ashes of land plants, wood, &c., were lixiviated, boiled, and evaporated to the dry substance called pot-ashes. It was discovered by Davy in 1807.

SOURCES WHENCE DERIVED.

Our daily food, made up of animal and vegetable substances, most of which contain salts of potassium, conveys to the human body this metal, which appears, in combination with other elements, to be an essential constituent of flesh, milk, &c.

This element is very plentifully distributed throughout the mineral world. It is found as a nitrate in the soils of certain hot climates; in sea-water, in certain springs, also in salt deposits are to be found iodides, bromides, and chlorides of potassium. Feldspar and mica are examples of common mineral bodies that contain potassium in the form of silicates.

When plants and trees are burnt, the organic acids with which the potash was united are changed to carbonates, and thus the wood-ashes contain potassic carbonate (K_2CO_3). The commercial process now approved for obtaining potassium is that of decomposing potassic carbonate by charcoal. Crude tartar—formerly called bitartrate of potash, but now termed hydro-potassic tartar, being, in fact, the crust deposited from wine—is first heated in a covered crucible until all vapours cease escaping; the residue, a porous mass consisting of potassic carbonate and finely-divided charcoal, is broken up into lumps, and transferred to a wrought-iron bottle (such as that delineated on page 19), provided with an iron tube; the bottle is supported in a proper furnace, and, when red hot, is dusted over with powdered fused borax: this simple coating protects the bottle from oxidation, and enables the heat to be gradually raised to a full white heat. When the vapour of potassium begins to appear and burns with a brilliant light, a peculiar shaped receiver is attached,

and kept cool with a damp cloth. The receiver is attached as close as possible to the generating-bottle, and, should the potassium choke up the neck, a provision is made to remove the obstruction with a sliding rod. Finally, the receiver is plunged into Persian naphtha, and when cold the potassium is removed and preserved under naphtha. The crude potassium is always redistilled, to get rid of a peculiar black detonating compound, and, when required very pure, is even distilled again.

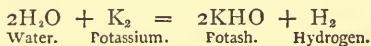
PHYSICAL PROPERTIES OF POTASSIUM.

This metal has a specific gravity of 0·865, and is the lightest of all metals except lithium: its specific gravity shows that it will float on water. At 0° F. it is crystalline and brittle, and at ordinary temperatures is very malleable—or rather, in this case, soft and pasty—and becomes perfectly liquid at 144° 5' F. Two clean surfaces are easily welded or squeezed together; indeed, the ordinary terms as applied to other metals—such as malleability, ductility, and tenacity—may be exchanged for the general one of plasticity.

Potassium is a bluish-white metal, and, when freshly cut, retains its brilliancy for a short time only, being speedily covered with oxide. Potassium may be crystallized by melting some in a sealed tube, and just at the point of solidification, when a few solid points appear, if the fluid portion is poured away by inverting the tube, the residue crystallizes in the form of shining octohedral crystals.

CHEMICAL PROPERTIES.

Potassium burns with a violet light when heated in the air, or, if thrown on water, is so rapidly oxidized and heated that the escaping hydrogen takes fire, and burns with a rose-red flame, because some of the potassium volatilizes and burns with it. The resulting potassic hydrate (KHO) takes the form of a liquid red-hot ball, and, gradually cooling, appears like glass; and then coming in contact with the water, from which it was repelled whilst hot by the escaping vapour on the spheroidal system, it bursts into a number of small particles, any one of which entering the eye would cause great pain. Each atom of potassium displaces half the hydrogen of an atom of water, and potassium hydrate is formed.



There are three distinct oxides of potassium, viz.—

1. Potassium dioxide K_2O_2
2. Potash or potassium monoxide K_2O
3. Potassium tetroxide or peroxide of potassium K_2O_4

The chief salts of this metal are potassium carbonate (K_2CO_3); potassium nitrate, nitre or saltpetre (KNO_3), used so extensively in the manufacture of gunpowder, which contains

Nitre	75 parts by weight,
Charcoal	15 " "
Sulphur	10 " "

100;

Potassium chlorate (KClO_3), already mentioned as an important source of oxygen gas; and potassium sulphate (K_2SO_4).

Potassium forms various compounds with sulphur, viz.— K_2S , K_2S_2 , K_2S_3 , and K_2S_5 . It also unites with chlorine, iodine, bromine, and fluorine, and curiously absorbs a large quantity of hydrogen (HK_4) at a dull red heat, but gives off the gas again at a higher temperature.

The tests for salts of potassium are applied after all other metals except sodium are removed. The solutions tested should be concentrated, and for this purpose hard porcelain dishes, with or without handles, also strainers and ladles for dipping out any crystals for examination with a magnifying-glass, can be obtained from Mr. How.

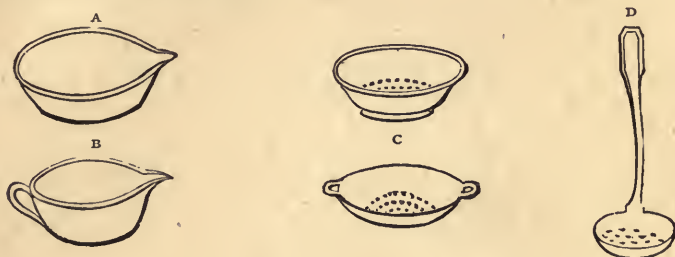


FIG. 50.

A, B, evaporating-dishes; C, D, porcelain strainers.

The concentrated fluid supposed to contain potash is tested with a solution of tartaric acid in excess, and, if briskly stirred, crystals of hydro-potassic tartrate ($KHC_4H_4O_6$) are formed. The best test is platonic chloride, which forms a yellow double salt with potash ($2KCl$, $PtCl_4$), insoluble in alcohol and ether, but slightly soluble in water.

SODIUM.

Symbol, Na (Natrium). Atomic weight, 23.

This metal was also discovered by Davy in 1808, and is so called from the alkali soda, originally obtained from the ashes of the Salsola soda.

SOURCES WHENCE DERIVED.

Sodic chloride, or common salt, is of course the great source from which this metal is obtained. Sodic chloride exists in solid beds in Cheshire, or is obtained by the evaporation of sea-water. Common salt is converted into sodic carbonate, and from this, by the action of charcoal mixed with chalk, and with the assistance of an intense heat, sodium is now obtained at a very cheap rate. The process is very much like that required in the manufacture of potassium, and the metal is now used extensively in the preparation of aluminium, magnesium, &c.

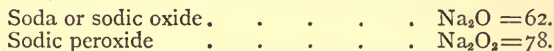
PHYSICAL PROPERTIES.

Sodium is a silver-white metal with a bluish aspect, plastic and soft like potassium at ordinary temperatures, and fusing at $207^{\circ} 7' F$. When dropped

into cold water it does not appear to produce enough heat to set fire to the hydrogen escaping around it; if, however, the water is thickened with starch, or hot, or if the sodium is placed on a piece of wetted blotting-paper, the heat accumulates, and then the hydrogen burns with the metal, which emits a bright yellow light. The specific gravity of sodium is 0.972.

CHEMICAL PROPERTIES.

Sodium volatilizes at a heat below redness; it tarnishes directly it is exposed to the air, and forms two oxides:



The chief salts are sodic chloride (NaCl), sodic nitrate or *cubic nitre* (NaNO_3), and sodic carbonate (Na_2CO_3); the latter represents in its manufacture one of the great commercial elements of wealth in this country, and involves processes conducted on the largest scale by which common salt is converted into "salt cake," then into "black ash," and finally, by lixiviation and evaporation, the soda-ash—viz., the carbonate—is obtained.

The phosphates of sodium, sodium borate, or borax ($\text{Na}_2\text{O}_2, \text{B}_2\text{O}_3 + 10\text{H}_2\text{O}$), the sodic silicates or soluble glass, and sodic hyposulphite ($\text{Na}_2\text{S}_2\text{H}_2\text{O}_4 + 4\text{H}_2\text{O}$), used in photography, are other examples of useful sodium salts.

Sodium is recognized by the yellow colour it imparts to flame, and all the sodium salts except the antimoniate being soluble in water, the detection of this metal is effected rather by a negative than a direct process. The spectroscope is most usefully applied in this and many other cases where the presence of a minute quantity of any metal is suspected.

RUBIDIUM.

Symbol, Rb. Atomic weight, 85.54.

This metal, so called from the Latin *rubidus*, dark red, was first discovered with the spectroscope by Bunsen and Kirchhoff between 1860 and '61. It is said to be a white metal capable of rapid oxidation, and having a specific gravity of 1.52. It is present in small quantities in lepidolite, and was originally discovered in the mineral water of Dürkheim. At 14°F . it is soft, and melts at $101^\circ 3' \text{F}$. At a temperature below a dull red heat it is converted into a blue vapour shaded with green. Like potassium, rubidium takes fire when thrown upon water.

Rubidia (Rb_2O) is the only oxide of rubidium known, and rubidic chloride, sulphate, nitrate, carbonate, and hydro-rubidic carbonate or bicarbonate are some of the salts of this rare metal which have already been investigated.

CÆSIUM.

Symbol, Cs. Atomic weight, 133.

This metal was also discovered by spectrum analysis, and so called by its discoverers, Bunsen and Kirchhoff, from *cæsius*, sky-blue, in allusion to the two brilliant blue bands produced by it in the flame used for its volatilization.

Some idea of the searching nature of spectrum analysis may be formed from the fact that 140 gallons of the Dürkheim water in which it was first discovered contain only one grain of a salt of caesium. Pisani has, however, discovered caesium in a rare mineral called Pollux, found in the island of Elba: the mineral contained 32 per cent. of caesium.

Cæsia (Cs_2O), caësic chloride (CsCl), caësic sulphate (Cs_2SO_4), caësic nitrate (CsNO_3), and caësic carbonate (Cs_2CO_3) are some of the compounds of this metal which have been obtained.

Both rubidium and caesium closely resemble each other and potassium, and caesium is separated from rubidium by taking advantage of the greater solubility of the caësic tartrate.

LITHIUM.

Symbol, Li. Atomic weight, 7.

Lithium (from $\lambda\iota\theta\omicron\varsigma$, a stone) was formerly supposed to be a very rare metal, but, since the use of the spectroscope, is found to be contained in various mineral springs, the ashes of tobacco, and in certain micas and feldspars. Lepidolite or lithic mica, triphane or spodumene, and petalite are the three minerals that contain it in the largest quantity, and even that is small, and does not exceed from 3 to 6 per cent.

The specific gravity of lithium (the lightest solid known) is only 0.5936. It volatilizes at high temperatures. If thrown on water it behaves very much like sodium, and produces a most intense heat when burnt in the air. It is usually prepared by decomposing the fused chloride by electricity. The metal is of a white colour, and melts at 356°F .

Lithia (L_2O), lithic hydrate (LHO), lithic chloride, sulphate, phosphate, and carbonate have been examined, and all the volatile lithium salts impart a beautiful crimson tinge to flame. The spectrum of lithium is one of the most beautiful that can be projected on to the disc by the electric lamp and voltaic battery.

AMMONIUM.

Theoretical atomic weight = 18.

It has long been supposed that there exists another metal, or *quasi* metal (NH_4), called ammonium; thus ammonium chloride (H_4NCl), the most important of the salts derived from ammonium, when employed in solution to moisten an amalgam of potassium and sodium, causes the latter to increase eight or ten times in bulk. The appearance of the swelled-out amalgam is peculiar: it retains its brilliancy, at the same time appears pasty; and if this body is reduced in temperature to zero or 0°F ., it assumes the solid condition, and crystallizes in cubes. In the pasty state it gradually decomposes spontaneously, but more rapidly when placed in water, when *hydrogen* escapes, and ammonia is found in solution. A metal is always defined to be an element; how then can NH_4 belong to that class? Is it not more probable that hydrogen is really the metal that puffs out and combines with the mercury? The idea receives a remarkable corroboration from the following experiment, which the writer was kindly shown by Mr. Roberts:

"Hydrogenium a Metal.—At the Royal Society's *conversazione*, Mr. W. C. Roberts (for Mr. Graham, the Master of the Mint) exhibited a curious example of the absorption of hydrogen by palladium, and consequent alloy and expansion of the metal. A coiled ribbon of palladium was attached to each pole of a small battery in a water bath. The current being turned on, the ribbon absorbs hydrogen, expands, uncoils, and stretches itself across the bath; then, on reversal of the current, shrinks, and re-forms its coil, while the opposite ribbon goes through the opposite process. The appearance is that of two worms wriggling alternately to and fro across the bath. In another instance the expansion was shown by a red-tipped arrow making bold sweeps half round a circle. These experiments demonstrate the enormous capacity of palladium for absorption of hydrogen, and verify Mr. Graham's conclusions."

CLASS II.

CALCIUM, STRONTIUM, BARIUM.

Metals of the Alkaline Earths.

CALCIUM.

Symbol, Ca. Atomic weight, 40.

Mountain limestone, marble, chalk, gypsum, marls, and various soils are all common sources from whence this metal may be derived. It is, however, usually procured from calcium iodide by the action of metallic sodium, and is then described as a yellow metal, like pale gold, having a specific gravity of 1.580. Calcium was discovered by Davy in the year 1808, and obtained by him from lime, a substance long called a calx or earth. In hardness calcium takes an intermediate position between gold and lead, and can be beaten into very thin leaves. When exposed to dry or damp air, it tarnishes and is gradually oxidized. When heated, it burns with a white light, forming the only oxide, called calcic oxide or lime (CaO), sometimes termed *quicklime*, to distinguish it from the hydrate of lime or calcic hydrate (CaH_2O_2).

The use of lime in the mixtures called mortars and cements, also in hydraulic mortars, and for many other useful purposes, is well known. The salts of lime are far too numerous to be considered here. The most important are calcic carbonate (CaCO_3), calcic sulphate (CaSO_4), calcic phosphate ($\text{Ca}_3\text{P}_2\text{O}_8$), and calcic fluoride (CaF_2).

STRONTIUM.

Symbol, Sr. Atomic weight, 87.5.

Another of the metals discovered by Davy in 1808, and so called because obtained from a mineral originally noticed by Dr. Hope, and called strontianite, the strontic or strontium carbonate (SrCO_3).

It is a yellow metal, having a specific gravity of 2.54, which is malleable, and has a certain amount of tenacity, and burns, when heated in the air, with a crimson flame emitting sparks. It decomposes water. The only oxide is strontia (SrO). The most important salt is strontic nitrate (Sr_2NO_3), now

used extensively in all pyrotechnic displays in consequence of the marked red which it imparts to flame. The other important salts, both of which occur native, are strontic carbonate (SrCO_3), and strontic sulphate (SrSO_4).

BARIUM.

Symbol, Ba. Atomic weight, 137.

There is a mineral called "heavy spar," containing baryten, so called from *βαρύς* (heavy); it is a sulphate of barium or baric sulphate (BaSO_4), and it has given the name to this metal. Discovered, like the preceding ones of this class, by Davy, in 1808.

It is a pale yellow metal, the specific gravity of which has not yet been determined. Barium decomposes water and is quickly oxidized in the air. It forms two oxides: baryta or baric oxide (BaO), and baric dioxide or peroxide of barium (BaO_2).

The chief salts are baric chloride or chloride of barium ($\text{BaCl}_2, 2\text{H}_2\text{O}$), baric sulphate (BaSO_4), which occurs native, and is used for adulterating white lead, and baric nitrate (Ba_2NO_3), used in common with the baric chloride as the chief test for sulphates. Baric nitrate is likewise employed in pyrotechnic mixtures to impart a green colour to the fire.

Baric carbonate (BaCO_3), occurs native, and is called *witherite*.

The metals of this class all form insoluble carbonates, oxalates, sulphates, and phosphates.

CLASS III.

ALUMINIUM, GLUCINIUM, ZIRCONIUM, THORIUM, YTTRIUM, ERBIUM, CERIUM, LANTHANUM, DIDYMIUM.

*Metals of the Earths.**

ALUMINIUM.

Symbol, Al. Atomic weight, 27.5.

Every kind of clay representing compounds of aluminium with silica, called scientifically hydrated aluminic silicate, whether it be common clay, pipeclay, blue clay, loam, or fire-clay, or the more valuable form called kaolin—the porcelain clay of china, or Cornish stone, yellow ochre, red bole, fullers' earth,—all contain this metal.

The perfect productions of Sévres are said to be made of a composition consisting of

Washed kaolin	.	.	.	.	62 parts
Aumont sand	.	.	.	.	17 "
Quartz or feldspar	.	.	.	.	17 "
Bougival chalk	.	.	.	.	4 "

100

* Of these, aluminium only will be considered, as the other metals of this class do not present features of any interest to the general reader.

The first step in the preparation of aluminium is the production of alum from the alum schist or alum ore found near Glasgow and at Whitby in Yorkshire; indeed, the metal is so called from *alumen*, clay, and was discovered by Davy in 1808. It is, however, from the aluminium chloride or chloride of aluminium (Al_2Cl_6) that the metal is usually procured.

The following is M. St. Claire Deville's process for obtaining this metal:

"Introduce into a glass tube of about an inch in diameter from 200 to 300 grammes of chloride of aluminium, closing the ends with a plug of asbestos;



FIG. 51.—*Sèvres Porcelain, French Exhibition, 1867.*

then conduct hydrogen gas, dry and perfectly free from atmospheric air, into the tube, and heat the chloride of aluminium in this current of gas by means of charcoal. This will have the effect of driving off the hydrochloric acid, chloride of silicon, and chloride of sulphur, with which it is always impregnated. Capsules of as large size as possible, containing each some grammes of sodium, previously crushed between two sheets of dry filter-paper, are then introduced into the glass tube. The tube being full of hydrogen, the sodium is melted; and the chloride of aluminium, on being heated, will be distilled and decomposed with incandescence, which may be easily moderated. The operation will be complete when all the sodium has disappeared, and the chloride of sodium formed has absorbed a sufficient quantity of chloride of aluminium to saturate it. The aluminium will now exist in the state of a double chloride of aluminium and sodium, which is a very fusible and volatile compound. The capsules are next to be removed from the glass tube, and placed in a large porcelain tube furnished with a pipe leading to a receiver. Through this porcelain tube, while heated to a lively red heat, a current of hydrogen, dry and free from air, is caused to pass, and the chloride of alumi-

nium and sodium will be thereby distilled without decomposition, and collect in the receiver. After the operation all the aluminium will be found collected in the capsules in the form of large globules; these are washed in water, which will carry off a little of the salt produced by reaction, and also some brown silicium. In order to form a single mass of all these globules, after being cleansed and dried they are introduced into a capsule of porcelain, into which is put, as a flux, a small quantity of the product of the preceding operation—*i.e.*, of the double chloride of aluminium and sodium. On heating the capsule in a muffle to the temperature of about the melting-point of silver, all the globules will be seen to unite in a brilliant mass, which is allowed to cool, and then washed. The melted metal must be kept in a closed porcelain crucible until the vapours of the chloride of aluminium and sodium with which the metal is impregnated have entirely disappeared. The metallic mass will then be found surrounded by a light pellicle of alumina arising from the partial decomposition of the flux."

Messrs. Bell, of Newcastle, have perfected a convenient process, which works very admirably. They heat in a reverberatory furnace the double salt the sodio-aluminic chloride ($\text{NaCl}, \text{AlCl}_3$) with fluor spar or cryolite and metallic sodium; a very powerful action occurs, and large quantities of aluminium are obtained.

Aluminium is a white metal, very much like zinc, and is malleable and ductile: it can be rolled into sheets or drawn into wire, and, when cast into long bars and struck with a wooden rod, is very sonorous, the vibrations continuing for a considerable length of time after the blow is given.

Aluminium is remarkably light, having a specific gravity of only 2.6, so that it is rather more than two-and-a-half times heavier than water, and is therefore used for a great variety of useful and ornamental purposes where lightness is desirable.

The only oxide known is alumina (Al_2O_3), the basis of all clays, which in the native crystalline state is known in the form of corundum and emery, or the costly jewels, the ruby and sapphire. The specific gravity of the ruby is 3.95.

Alumina is one of the most valuable mordants known in the arts of dyeing and calico printing.

The most important salts of aluminium are aluminic chloride (Al_2Cl_6), aluminic sulphate ($\text{Al}_2(\text{SO}_4)_3, 18\text{H}_2\text{O}$), and alum or potassio-aluminic sulphate ($\text{KAl}_2(\text{SO}_4)_4, 12\text{H}_2\text{O}$). There are other varieties of alum obtained by substituting for the one atom of potassium an equivalent of sodium or ammonium; and if iron, chromium, or manganese are substituted for the aluminium, what is termed iron, chrome, and manganese alums are produced, of which one example may suffice,—iron alum ($\text{KFe}_2(\text{SO}_4)_6, 12\text{H}_2\text{O}$). In this it will be noticed that Fe_2SO_4 is substituted for Al_2SO_4 .

CLASS IV. MAGNESIUM, ZINC, CADMIUM.

The Zinc Class.

MAGNESIUM.

Symbol, Mg. Atomic weight, 24.3.

Sea-water, many springs, but especially the mountain limestone or dolomite is to be regarded as the chief source of magnesium, so called because it was originally brought from Magnesia in Asia Minor. Magnesium has assumed an important position amongst the metals on account of its useful employment as a means of producing a brilliant artificial light. The manufacture and the uses of the metal have been so lately described in the "*Mechanic's Magazine*,"* that extracts from this thoroughly practical thesis will be given here.

"Magnesium was one of Sir Humphrey Davy's many discoveries. He proved, in 1808, with the galvanic battery of the Royal Society, that magnesia was a compound of a metal with oxygen,—in a word, was the ash of a burnt metal. The fact lay dormant for many years: a new entry was simply made in the catalogue of elements. Bussy, the Paris chemist, exhibited, about 1830, the metal in larger quantities than had yet been obtained: he treated magnesium chloride with potassium, when the potassium, combining with the chlorine, left the magnesium in the metallic state. There discovery again rested until about 1856, when Deville and Caron taught chemists how to procure the metal with greater ease by substituting sodium for potassium. Bunsen, of Heidelberg, and Roscoe, of Manchester, shortly after proclaimed its value as a source of light. Thus science did her work: it remained for practical skill to coin her hints into current commercial service. The matter was taken up at this point by Mr. Edward Sonstadt, a young Englishman with a name derived from Swedish ancestry. Why, he asked, should not the laboratory process of Deville and Caron be so far improved as to be capable of being worked on a large manufacturing scale? and resolved to devote his energies to the solution of the question. Happily, he succeeded. After upwards of a year's experimenting, he persuaded some gentlemen to join him; a Company for the production of magnesium was formed, and business commenced in Manchester. The metallurgical process conducted on the Company's premises in Springfield Lane, Salford, is as follows:

"Lumps of rock magnesia (carbonate of magnesia) are placed in large jars, into which hydrochloric acid in aqueous solution is poured. Chemical action at once ensues: the chlorine and the magnesium embrace, and the oxygen and carbon pass off in the form of carbonic acid. The result is magnesium in combination with chlorine instead of with oxygen. The problem now is to dissolve this new alliance,—to get rid of the chlorine, and so obtain the magnesium. First the water must be evaporated, which would be easy enough if not attended with a peculiar danger. To get the magnesium chloride perfectly dry, it is necessary to bring it to a red heat; but this would result in the metal



FIG. 52.—*Magnesium Balloons at the Crystal Palace.*

dropping its novel acquaintance with chlorine and resuming its ancient union with oxygen. To avert this re-combination, the magnesium chloride, whilst yet in solution, is mixed with sodium chloride (*i.e.*, common salt) or potassium chloride, and, thus fortified, the aggressions of oxygen whilst drying are kept off. The mixture is exposed in broad open pans over stoves, and when sufficiently dry the double salt is scraped together and placed in an iron crucible, in which it is heated until melted, whereby the last traces of water are driven off; it is then stowed away until required in air-tight vessels to prevent deliquescence. Here comes in that curious metal, sodium, also discovered by Davy.

“Having, then, got together sodium and dry magnesium chloride, all is ready for the production of the desired metal. Five parts of the magnesium chloride (mixed, however, as we have noted, with sodium chloride) to one part of sodium, are deposited in a strong iron crucible with a closely-fitting lid, which is screwed down. The crucible is placed in a furnace and heated to redness. The contents are thus fused together, when the sodium takes the chlorine from the magnesium. The crucible is then lifted from the fire and allowed to cool. When the lid is removed, a solid mass is discovered, which, when tumbled out and broken up, reveals magnesium in nuggets of various sizes and shapes, bright as silver, and like eggs, buttons, nuts, and pin-heads, and also in minute granules and black powder; all which is carefully separated and collected from the dross. The magnesium in this condition contains various impurities, the worst of which is uncombined sodium. From these it is delivered by distillation. The crude metal is placed in a crucible, through the bottom of which a tube ascends to within an inch of the lid; the tube leads to an iron box placed beneath the bars of the furnace, so that it may be kept cool. The lid being carefully fixed, the atmospheric air, as containing

oxygen, is expelled by the injection of hydrogen, and as the crucible becomes heated the magnesium rises in vapour, descends the upright central tube, and condenses in purity in the box below; it is subsequently melted and cast in ingots.

"When the Magnesium Company commenced business, it was fancied that their product might be used in jewellery, but a little experience dissipated the illusion. A fresh surface of magnesium is little inferior in appearance to silver; but it soon contracts from the dampness of the atmosphere a coat of oxide, which is fatal to its beauty. Gradually the Company were brought to the conclusion that they must find their market in the use of the metal as a source of light. For this their commodity had high qualifications. Its power was unequalled save by the electric light, and it has a peculiar charm in displaying colours as in sunshine.

"At the meeting of the British Association in Nottingham, Mr. Larkin lighted up the large refreshment-tent, including a temporary garden, for two evenings with a couple of his lamps, and obviated the necessity of laying on gas; and his invention has since been exhibited and tested on several similar important occasions. He has also devised a portable lamp for surveyors of mines and explorers of subterranean and dark places, which received the approval of practical men. We are as yet at the beginning of the uses of the magnesium light: its only real rival in illuminating power is electricity, which, however, is not likely to compete with it on the score of handiness and portability. It is true, magnesium is at present a costly material: it is retailed in powder at 5s. per oz.—the price of silver; though, it is to be noted, an ounce of magnesium is six times the bulk of an ounce of silver. Moreover, the manufacturers assure us that as the consumption increases the price will fall. Probably some chemist will find out how to dispense with sodium in extracting it from the ore, or else how to obtain sodium more cheaply. The price of magnesium is ruled by that of sodium: all else connected with its working is of comparatively small importance. The qualities and merits of the magnesium light are now familiar to most people: these have been displayed with great effect by means of the balloons sent up from the Crystal Palace, with rockets attached primed with magnesium filings and chlorate of potash. The rockets, as they burn, illuminate the palace and the surrounding country with a radiance between sunshine and moonshine, and display the countenances and dresses of the gazing crowd, and the flowers and foliage of the garden, in the tints of daylight. For fireworks magnesium serves as an ingredient of surpassing brilliancy; the makers, however, complain that its very excellence is an objection, for those who see it once demand it always, to the prejudice of the commoner and less costly articles."

There is only one oxide of magnesium, viz., magnesia (MgO).

The important salts of this metal are magnesian chloride (MgCl_2), the source of the metal, magnesian sulphate or Epsom salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), and magnesian carbonate (MgCO_3).

The magnesian silicates occur in nature, some of the most familiar being talc ($4\text{MgO} \cdot 5\text{SiO}_2$), steatite, French chalk or soapstone, and meerschaum, or hydrated silicate of magnesia.

The phosphates of magnesium are important in analytical chemistry, the ammonio-magnesian phosphate ($\text{MgH}_4\text{N}_2\text{PO}_4 \cdot 6\text{H}_2\text{O}$) being the product obtained when solution of hydro-disodic phosphate, mixed with that of ammonium chloride, is added to one of a magnesian salt.

ZINC.

Symbol, Zn. Atomic weight, 65.2.

This metal, it is stated by Griffiths, "was first thus called in the writings of Paracelsus, about the year 1540. The term is probably derived from the German word *zinken*, signifying 'nails,' and applied to this metal on account of its frequently forming pointed particles somewhat resembling nails when melted and suddenly poured into water."



FIG. 53.—Zinc Casting, French Exhibition, 1867.

SOURCES WHENCE DERIVED.

It is obtained from the mines of Cornwall, Wales, Cumberland, and the Isle of Man, in the form of zincic sulphide (Blende or Black Jack), and zincic carbonate or calamine; is very abundant in England, and is found principally in the Mendip Hills and various parts of Somersetshire, at Holywell, Flintshire, at Castleton, Derbyshire, and in Cumberland.

In order to reduce the zincic sulphide or carbonate to the metallic state, the powdered ore is roasted or calcined, by which it loses about 20 per cent., and is converted into an oxide. It is then ground in a mill, and mixed with powdered coal, and strongly heated in large clay crucibles, so that, as the vapour of zinc is produced, it is distilled *per descensum*, and is condensed partly in powder and partly in irregular-shaped lumps, which fall into iron basins placed at the end of the pipe: this is constantly looked to, to prevent the zinc that distils over clogging it up. The crude metal is again melted and cast into ingots or sheets.

PHYSICAL PROPERTIES.

Zinc presents a beautiful crystalline structure if a thick bar or slab is broken with a sledge-hammer; its colour is a bluish-white. In bending zinc for battery purposes, it is soon found that if the metal is heated to about 300° F., it is much more manageable and does not break, and thus in rolling the zinc the slabs are always previously heated to 212° or 300° ; at a higher temperature it again becomes brittle, and melts at 773° F.

The specific gravity of zinc is 6.8 to 7.1. The "Building News," speaking with authority on the application of this metal to building and other purposes, says:

"This metal has been largely employed for pipes, for galvanic batteries used in working the electric telegraph, as a substitute for white lead, and as a constituent of brass and German silver.

"Zinc is, as is well known, largely obtained from Prussia; and we find that nearly 4,500,000 cwt. of zinc were obtained in 1857. In the seven large smelting establishments in Belgium and Prussia, belonging to the Vieille Montagne Company, there are 230 furnaces. Fifteen years ago the quantity of zinc used for roofing was not more than 5,000 tons; now, it appears, 23,000 tons of sheet zinc are annually made by this Company. For ship sheathing 3,500 tons are produced, although fifteen years ago zinc was not employed at all for this purpose. Stamped ornaments in zinc date only from 1852; now there are 1,500 tons produced for this object. For ships' sheathing zinc must necessarily be altogether free from impurity, or it will soon decay. But there can be no question about the usefulness of this metal for building purposes; and the fact that it is coming into still greater use and is becoming better known and appreciated is evidence that its reputation is increasing. With care in purchasing and laying there is but little doubt that it will turn out well. In Paris it has been used for nearly every roof formed for some years. The new markets, constructed of iron in 1856, have been covered with zinc, and, excepting in one place where the workmen were careless, the whole of the zinc is in capital condition. In Germany zinc for roofing is largely used, and the work is generally remarkable for solidity and closeness."

CHEMICAL PROPERTIES.

At a bright red heat and when exposed to the air zinc is rapidly oxidized, and then takes fire, burning with a bright greenish flame, and forming the only oxide of this metal, viz., the zinc oxide (ZnO), or what was formerly called the "flos philosophorum" or philosopher's wool, and now termed zinc white.

The chief salts of zinc are zincic sulphate ($\text{ZnSO}_4, 7\text{H}_2\text{O}$), also zincic chloride (ZnCl_2), used as a disinfectant under the name of "Burnett's Disinfecting Fluid." Zincic sulphide or blende (ZnS) and zincic carbonate or calamine (ZnCO_3) have already been spoken of as the natural compounds from which zinc is obtained.

 CADMIUM.

Symbol, Cd. Atomic weight, 112.

This metal was discovered in the ore of zinc by Stromeyer in 1817. It has a specific gravity of 8.6, is a white metal which fuses at 442° , and crystallizes in octohedral crystals.

Cadmic oxide or oxide of cadmium (CdO) is the only known oxide of this metal. Cadmic sulphide, chloride, and iodide are well-known salts of cadmium. The last-named, iodide, has already been mentioned in connection with the photographic art.

CLASS V.

IRON, MANGANESE, COBALT, NICKEL, CHROMIUM,
URANIUM, INDIUM.

The Iron Class.

IRON.

Symbol, Fe (Ferrum). Atomic weight, 56.

SOURCES WHENCE DERIVED.

In an orbit peculiar to themselves are supposed to revolve countless fragments of a solid nature, varying in weight from tons to pounds, ounces, and grains or mere dust: these bodies are called asteroids or planetary dust; and when they enter the atmosphere of the earth, they become ignited by friction in their very rapid movement through the upper portions of the air, and, when drawn within the sphere of the attraction of the earth, they fall into or upon our planet, and are then called "meteorites." These remarkable visitors contain a large proportion of pure metallic iron, also sulphur, phosphorus, carbon, manganese, magnesium, nickel, cobalt, tin, and copper.

Metallic iron in small quantities has been found associated with the ores of platinum. The ores of this metal are, however, legion, and amongst the most important are iron pyrites (FeS_2); clay ironstone, an impure carbonate, and the source of nearly all the enormous quantities of iron made in Great Britain; the hæmatites, red and brown (the former Fe_2O_3 , the latter $2\text{Fe}_2\text{O}_3, 3\text{H}_2\text{O}$); specular iron ore (also Fe_2O_3); and the magnetic iron ore or loadstone ($\text{FeO}, \text{Fe}_3\text{O}_4$).

The smelting of iron ore is a process which has been brought to the highest degree of perfection in this country; it is, therefore, interesting to notice first the more primitive and ancient method of reducing iron ore to the metallic state, such as that illustrated in Fig. 515, and carried on by the natives in India.

"Smelting of Iron Ore in Kasya Hills.—The following is the method pursued from time immemorial by the natives of this part of the country in working down the ores of iron so plentifully met with hereby. There are large grass huts at least 25 ft. high, the thatch of which reaches down to the ground on all sides; the interior, of an oval form, 15 by 30 ft. in the two diameters, is divided into three apartments, the central one being the smelting-room. Two large double bellows, with the nozzles pointed downwards, are set up on one side of the apartment, on the upper side of which a man stands with one foot on each, his back supported by two planks. He holds a stick in his left hand, which is suspended from the roof, and has two straps attached to it below, connected with the two bellows: these are worked quickly by a wriggling motion of the loins and the strength of the leg. The nozzles of the bellows unite in a tube which leads underground, from a sort of wind-chest, to the hearth,



FIG. 54.—*Smelting Iron Ore in India.*

about four feet in front of them. Over the hearth is a chimney of pipeclay, braced with iron hoops, 2 ft. in diameter at the bottom and about 6 ft. high; the mouth at the bottom is on the side away from the bellows, and the chimney inclined from them, to direct the heated air from the smelter towards an opening in the roof. At the right side of the bellows, and even with the top of the chimney, is a trough containing damp charcoal and ironsand. At every motion of his body the operator with a long spoon tumbles a piece of this charcoal, with the ironsand adhering to it, down the funnel of the furnace; and when a mass of melted—or rather softened—iron is formed on the hearth, it is

taken out with the tongs, and beaten with a heavy wooden mallet on a large stone by way of anvil. The iron in this state is sent down to the plains for sale or barter.”*

Herodotus tells us that amongst the most precious gifts presented by the Indian monarch Porus to Alexander the Great was a pound of steel, the value of which at that period, according to a rough calculation of the elder Mueset, may be estimated at about £40. A pound of steel, at present prices of £14 a ton, costs, within a fraction, three-halfpence of our money. That the manufacture of steel was in later ages carried to great perfection in India, as well as in the South of Europe, especially in its application to warlike instruments, as swords, spear-heads, daggers, and the like, we have abundant evidence in specimens of ancient art.

In commerce iron is known and used in three different conditions, viz., cast iron, wrought iron, and steel. Each of these forms exhibits special physical properties, and all differ essentially in their chemical constitution.

As a contrast to the ancient method of smelting iron ore in India, we have in England the immense “blast furnace,” 50 ft. high and from 14 to 17 ft. in diameter. The crude materials are roasted clay ironstone, coal, and limestone: these, with the assistance of a powerful blast of air, react on each other: the carbon deoxidizes the oxide of iron, and the limestone is the flux which melts with and carries off the earthy matter. The iron falls down and collects in what is called the crucible or hearth, and is run into rough sand moulds, and when cold is called “pig” or “cast” iron.

By the last official returns, taken from Hunt, the total quantity of iron ore raised in the United Kingdom, in 1867, amounted to 10,021,058 tons 9 cwt., the estimated value of which was £3,210,098 os. 4d. Foreign ores imported, 86,568 tons. Total quantity of iron ore converted into pig iron, 10,107,626 tons. The number of furnaces in blast were 55½.

Pig iron produced:

	Tons.
In England	2,810,946½
„ Wales	919,077
„ Scotland	1,031,000

Total production of pig iron in Great Britain 4,761,023½

This quantity, estimated at the mean average cost at the place of production, would have a value of £11,902,557. Into this large amount of ore Northamptonshire enters for 416,765 tons, of the estimated value of £104,191; and the North Riding of Yorkshire, or the Cleveland district, produced 2,739,033 tons, of the estimated value of £798,056. The total produce of iron ore in Scotland in the same year was 1,264,800 tons, of the estimated value of £311,200, both returns being less than the corresponding returns of the preceding year. Such are the most recent returns of a manufacture which gives direct employment to 250,000 persons, and the prosperity of which, or the reverse, affects the comforts or privations of so many thousands of our fellow-countrymen.

Pig or crude cast iron contains many foreign bodies which interfere with its use for purposes where tough, good iron is required. There are three varieties of cast iron, viz., grey, mottled, and white cast iron. They contain combined

carbon, graphite diffused through the metal, silicon, sulphur, phosphorus, iron, manganese, and sometimes, though rarely, copper, arsenic, cobalt, and chromium. To free the iron from these impurities, Mr. Cort invented and carried out the process of "puddling" iron, by which the carbon and other bodies were almost wholly taken out of the pig iron, and "wrought" or nearly pure iron obtained.

To convert wrought iron into steel, the carbon is again united by the tedious and costly process called "cementation," the "bar" or "wrought" iron being kept for some three weeks in a furnace surrounded with charcoal, until it has absorbed a sufficient quantity of solid carbon.

The most remarkable improvement in the manufacture of pig iron direct into wrought iron or into steel is undoubtedly that of Mr. Bessemer. The author of a very clever pamphlet on "Heaton's Process for the Treatment of Cast Iron in the Manufacture of Steel" (to be described presently), thus speaks of it:

"The enthusiasm with which the Bessemer process was welcomed in all parts of the world, in the year 1855, is still fresh in the recollection of all taking an interest in the iron trade. The invention excited a kind of frenzy. The very site where the experiments had been carried on derived fresh interest from the event. On the spot where Richard Baxter tried to save men's souls from fire eternal, Bessemer had studied as earnestly to save their bodies from fire temporal. The "heel-piece" for the "limping sinner" was replaced by the crucible for the sweating puddler. The making of iron bars, up to that time an operation of four successive fires, was now performed by one heat. After the melted iron had run out of the pig-producing furnace, the usual process had been to stir it by human labour, with a view to expose all parts of its interior and exterior to the action of the atmosphere, in order that the carbon, and other extraneous matter, might be burnt out by the aid of oxygen. Mr. Bessemer substituted for this the forcing of air by steam power through the molten metal. Thus, without any additional fuel in the furnace, the heat of the iron was not only kept up, but increased by the combustion of the oxygen mixing with the carbon in the interior of the molten metal, and the iron was rendered malleable, ready for the tilt-hammer, at a single heat."

After burning out the carbon and silicon from the pig iron—usually Lancashire hæmatite pig—the Bessemer steel is made by adding to the melted wrought iron such a quantity of pure cast iron as is necessary to give carbon enough to convert the whole mass into steel. The cast iron added usually contains 6 per cent. of carbon and 10 of manganese, and directly after it is added the steel is cast into ingots. Moreover, the whole process is carefully watched with the spectroscope, so that the person who directs the operations knows exactly, by the lines obtained from the flame of the furnace, when the carbon and silicon are burnt out, and the precise moment when the pure cast iron should be added. In this manner six tons of cast iron are converted into steel in twenty minutes.

It would be thought that such a process could not be surpassed; but the author of the pamphlet already referred to thus speaks of the rival process described by Mr. Heaton:

"It is at the Langley Mill Steel Works that Mr. Heaton has successfully developed the process which he has patented, which is one remarkably simple in practical working.

"An ordinary cupola furnace is charged with pig iron and coke, and fired

in the usual way, and the iron when melted is drawn off into a ladle, from which it is transferred to the converter.

"The converter is a wrought-iron pot lined with fire-brick. In the bottom is introduced a charge of crude nitrate of soda, usually in the proportion of 2 cwt. per ton of converted steel, usually but not invariably diluted with about 25 lbs. of siliceous sand. This charge is protected or covered over with a close-fitting perforated iron plate weighing about 100 lbs., the diameter of the plate being about 2 ft. The converter, with its contents, is then securely attached, by movable iron clamps, to the open mouth of a sheet-iron chimney, also lined for 6 ft. with fire-brick, and the melted iron, taken in a crane ladle from the cupola, is poured in. The subsequent part of the process is thus described by Professor Miller, of King's College, Vice-President of the Royal Society and Assayer to the Mint.

"In about two minutes,' writes the Professor in his preliminary report, dated the 14th of October, 'a reaction commenced. At first a moderate quantity of brown nitrous fumes escaped; these were followed by copious blackish, then grey, then whitish fumes, produced by the escape of steam, carrying with it in suspension a portion of the flux. After the lapse of five or six minutes, a violent deflagration occurred, attended with a loud roaring noise and a burst of a brilliant yellow flame from the top of the chimney. This lasted for about $1\frac{1}{2}$ minutes, and then subsided as rapidly as it commenced. When all had become tranquil, the converter was detached from the chimney, and its contents were emptied on to the iron pavement of the foundry.

"The crude steel was in a pasty state and the slag fluid; the cast-iron perforated plate, which was placed as a cover to the converter, had become melted up and incorporated with the charge of molten metal. The slag had a glassy or blebby appearance, and a dark or green colour in mass.'

"Professor Miller proceeds to detail the subsequent parts of the process, and the results of his analysis of some of the products.

"A mass of crude steel from the converter was then subjected to the hammer. About $4\frac{1}{2}$ cwt. of the crude steel was transferred to an empty but hot reverberatory furnace, where in about an hour's time it was converted into four blooms, each of which was hammered, rolled into square bars, cut up, passed through a heating furnace, and rolled into rod, varying in thickness from 1 in. to five-eighths of an inch.

"Three or four cwt. of the crude steel from the converter was transferred to a re-heating furnace, then hammered into flat cakes, which, when cold, were broken up and sorted by hand for the steel melter.

"Two fire-clay pots, charged with a little clean sand, were heated, and into each 42 lbs. of the cake steel was charged; in about six hours the melted metal was cast into an ingot.

"Two other similar pots were charged with 35 lbs. of the same cake steel, 7 lbs. of scrap steel, and 1 oz. of oxide of manganese. These also were poured into ingots. The steel was subsequently tilted, but was softer than was anticipated.

"These results on the whole are to be considered rather as experimental than as average working samples. I have, therefore, made an examination of the following samples only: No. 4, Crude Cupola Pig; No. 7, Hammered Crude Steel; No. 8, Rolled Steely Iron; No. 5, Slag from the converter.

"I shall first give the result of my analysis of the three samples of metal:

	CUPOLA. Pig (4).	CRUDE. Steel (7).	STEEL-IRON. (8).
Carbon	2'830	1'800	0'993
Silicon, with a little titanium	2'950	0'266	0'149
Sulphur	0'113	0'018	traces
Phosphorus	1'455	0'298	0'292
Arsenic	0'041	0'039	0'024
Manganese	0'318	0'090	0'088
Calcium	—	0'319	0'310
Sodium	—	0'144	traces
Iron (by difference)	92'293	97'026	98'144
	100'000	100'000	100'000

“It will be obvious from a comparison of these results that the reaction with the nitrate of soda has removed a large proportion of the carbon, silicon, and phosphorus, as well as most of the sulphur. The quantity of phosphorus (0'298 per cent.) retained by the sample of crude steel from the converter which I analysed, is obviously not such as to injure the quality.*

“The bar-iron was in our presence subjected to many severe tests. It was bent and hammered sharply round without cracking. It was forged and subjected to a similar trial, both at a dull red and a cherry red heat, without cracking; it also welded satisfactorily.

“The removal of the silicon is also a marked result of the action of the nitrate.

“It is obvious that the practical point to be attended to is to procure results which *shall be uniform*, so as to give steel of uniform quality when pig of similar composition is subjected to the process. The experiments of Mr. Kirkaldy on the tensile strength of various specimens afford strong evidence that such uniformity is attainable.

“I have not thought it necessary to make a *complete* analysis of the slag, but have determined the quantity of sand, silica, phosphoric and sulphuric acid, as well as the amount of iron, which it contains. It was less soluble in water than I had been led to expect, and it has not deliquesced though left in a paper parcel.

“I found that of 100 parts of the finely-powdered slag, 11'9 were soluble in water. The following was the result of my analysis:

Sand	47'3
Silica, in combination	6'1
Phosphoric acid	6'8
Sulphuric acid	1'1
Iron (a good deal of it as metal)	12'6
Soda and lime †	26'1
	100'0

“This result shows that a large proportion of phosphorus is extracted by

* It is important to point out that as no analysis of the finished steel tested by Mr. Kirkaldy is given, it is not improbable that this small per centage of phosphorus might have been still further reduced before it arrived at its final state of manufacture.

† The use of lime was exceptional. Its use is now discontinued; but its use on that occasion no doubt accounted for the slag being less deliquescent and soluble than it is usually found to be.

the oxidizing influence of the nitrate, and that a certain amount of the iron is mechanically diffused through the slag.

"The proportion of slag to the yield of crude steel-iron was not ascertained by direct experiment; but, calculating from the materials employed, its maximum amount could not have exceeded 23 per cent. of the weight of the charge of molten metal. Consequently, the 12.6 per cent. of iron in the slag would not be more than 3 per cent. of the iron operated on.

"In conclusion, I have no hesitation in stating that Heaton's process is based upon correct chemical principles: the mode of attaining the result is both simple and rapid. The nitric acid of the nitrate in this operation imparts oxygen to the impurities always present in cast iron, converting them into compounds which combine with the sodium; and these are removed with the sodium in the slag. This action of the sodium is one of the peculiar features of the process, and gives it an advantage over the oxidizing methods in common use."

"The slag produced is already utilized at the works, and forms the subject of a new and valuable patent. There is every reason to believe that the products of combustion may, by the means of a mechanical arrangement devised by Mr. Heaton, be further utilized, and afford a large set-off on the original cost of the nitrate. It is also a great question whether the phosphorus may not be most profitably reduced from the slag for commercial purposes."

PHYSICAL PROPERTIES OF IRON.

Pure iron has a bright white colour; though soft, it possesses great tenacity and toughness, and has a specific gravity of 7.844. It crystallizes in cubes, and, when made sufficiently hot, possesses the valuable property of cohering to another piece of iron, or what is termed "welding," when two clean hot surfaces are hammered together. Iron possesses in the highest degree the valuable properties of malleability, ductility, and tenacity, and has a curious susceptibility to magnetism.

CHEMICAL PROPERTIES.

Iron takes fire and burns in air, or still better in oxygen, and if obtained in the state of powder by reducing ferric oxide (Fe_2O_3) at a low red heat by hydrogen, it takes fire spontaneously when shaken into the air.

There are four definite oxides of iron, viz.—

Ferrous oxide or protoxide	FeO
Ferric oxide or sesquioxide	Fe_2O_3
The black oxide or magnetic oxide	Fe_3O_4
Ferric acid, not isolated, and known only in combination	H_2FeO_4

Amongst the chief salts of iron may be noticed ferrous sulphide (FeS), and ferric disulphide, the "iron pyrites" of nature (FeS_2); also the chlorides, iodides, and bromides of iron; ferrous carbonate and the silicates of iron; potassic ferro-cyanide or yellow prussiate of potash, and potassic ferri-cyanide or red prussiate, yielding, with a neutral or acid solution of a ferrous salt, "Prussian blue" ($\text{Fe}_32\text{FeCy}_6, 12\text{H}_2\text{O}$)

MANGANESE.

Symbol, Mn. Atomic weight, 55.

A metal discovered by Gahn in 1775 in an ore examined by Scheele, and called by the latter manganese; but why he gave it that name is known only Swedish etymology.

The most important source of this metal is the natural mineral called the black oxide of manganese (MnO_2), used so largely for making oxygen gas and chlorine, and likewise employed to impart a purple colour to glass.

Manganese is a greyish-white metal, having a specific gravity of 8.013, and, although brittle, is hard enough to scratch steel. It decomposes water slowly, and can only be preserved in the metallic state (like potassium) by immersing it in Persian naphtha. It is feebly magnetic, and is said to exhale a peculiar odour when handled. There are various oxides of this metal:

Manganous oxide or protoxide	MnO
Manganic oxide or sesquioxide	Mn_2O_3
Mangano-manganic oxide or red oxide	Mn_3O_4
Manganese dioxide or black oxide	MnO_2

Also two other compounds of oxygen and manganese, known only in combination as salts, viz.—

Potassic manganate	K_2MnO_4
Potassic permanganate	KMnO_4

The latter salts are now largely employed as disinfectants, because they have the power of oxidizing organic matter, and for that reason are used in certain processes as bleaching agents. The salts of manganese are too numerous to discuss here.

COBALT.

Symbol, Co. Atomic weight, 58.7.

This metal was discovered by Brandt in 1733, and was so named after a sprite or spirit that greatly troubled the miners in the German mines, and called by them *kobold*. It is a rare metal, reddish-white, and having a specific gravity of 8.5. Cobalt is extremely infusible, and, like iron in many respects, is also very tenacious and magnetic.

There are two oxides of cobalt:

Cobaltous oxide or protoxide	CoO
Cobaltic oxide or sesquioxide	Co_2O_3

The protoxide is a valuable article in commerce, because it is used to impart the blue colour to porcelain and pottery, and when combined with glass is called smalt, a lovely blue used largely by paper-stainers. Cobalt is easily recognized by the blue colour it imparts to borax in the oxidating flame of the blowpipe.

The important salts are the sulphide, chloride, sulphate, nitrate, and carbonate of cobalt.

NICKEL.

Symbol, Ni. Atomic weight, 58·7.

The so-called "false copper," or "*kupfer nickel*" of the German miners, has given the name to this metal, discovered by Cronstedt in 1751. This mineral is an arsenide of nickel (NiAs), and contains 44 parts of nickel and 56 of arsenic. "Speiss" is an impure arsenio-sulphide of nickel. Nickel is largely made and used in Birmingham in the manufacture of "German silver," an alloy of 18·4 nickel, 30·6 zinc, and 51 copper. Nickel is a white metal, having a specific gravity of 8·82. Although hard, it is both malleable and ductile, and, like the other metals belonging to this class, is feebly magnetic, losing that power entirely at 626°F .

There are two oxides of nickel,—the protoxide (NiO) and the sesquioxide (Ni_2O_3). The chief compounds of this metal are the sulphide of nickel, also nickel chloride, sulphate, and carbonate.

The salts of nickel impart a reddish-yellow colour to borax fused in the oxidating flame of the blowpipe.

CHROMIUM.

Symbol, Cr. Atomic weight, 52·5.

The name of this metal—taken from the Greek $\chi\rho\omicron\mu\alpha$, colour—is very suggestive of its important use in the preparation of certain pigments and in calico printing. This metal was discovered by Vauquelin in plumbic chromate in 1797. The most important ore containing it is the chrome iron-stone ($\text{FeO}, \text{Cr}_2\text{O}_3$), found chiefly in Sweden and North America. Chromium is very infusible, perhaps the most so of all the metals, and it has a specific gravity of 6·81.

There are four compounds of chromium and oxygen, of which the sesquioxide is the most valuable, whilst the chromates are largely used in the manufacture of pigments, &c.

Chromous oxide or protoxide of chromium	CrO
Chromic sesquioxide	Cr_2O_3
Chromo-chromic oxide	$\text{CrO}, \text{Cr}_2\text{O}_3$
Chromic trioxide or chromic acid	CrO_3

The chief salts are the chromates, chromic chloride, sulphate, and nitrate.

URANIUM.

Symbol, U. Atomic weight, 120.

In the same year that Klaproth discovered this metal—viz., in 1789—Herschel had discovered the planet which now bears the same name, and in honour of the discoverer of the new planet the distinguished chemist gave it the name of uranium. The mineral called pitchblende contains nearly 80 per cent. of the black uranium oxide ($2\text{UO}, \text{U}_2\text{O}_3$); it also constitutes a part of the two minerals termed chalcilite and uranite or hydrated calcic diuranic phosphate.

Uranium is described as a steel-white metal, analogous in its chemical re-

lations to iron and manganese. There are two well-marked oxides, uranous oxide or protoxide (UO), and uranic oxide or sesquioxide (U_2O_3).

The salts of uranium are green, such as the chlorides U_2Cl_3 and UCl .

The chief use of this metal is in glass staining, the uranous oxide imparting a perfect black, and the uranic oxide a yellow, which shines most curiously in light containing Stokes's rays, or in those that exist beyond the extreme violet.

INDIUM.

Symbol, In. Atomic weight, 74.

Discovered by Reich and Richter in zinc blende, from the peculiar lines obtained by heating this substance in the Bunsen flame, and then viewing it with the spectroscope. Two bright lines were seen in the blue and indigo rays of the spectrum, not coincident with any other known element. It is stated to be a white malleable metal, having a specific gravity of about 7.36, and is easily fusible.

Indic oxide is white. A yellow sulphide and a white chloride or acetate of indium have already been obtained and experimented with.

CLASS VI.

TIN, TITANIUM, NIOBIUM, TANTALUM.

The Tin Class.

TIN.

Symbol, Sn (Stannum). Atomic weight, 118.

This metal appears to have been known from the earliest periods, and is even mentioned in the books of Moses. Fig. 55 will remind the reader that it is chiefly obtained from Cornwall and Devonshire, from the ore called *tin-stone*, stannic oxide or binoxide of tin (SnO_2). Tin is a yellowish-white metal, having a specific gravity of 7.292: it is malleable, and is sold in sheets called "tin foil," used largely with mercury in the silvering of looking-glasses.

The alloys of tin are very important. Tinned iron or tin plate, Britannia metal, solder, speculum, bell and gun metal, and bronze are all illustrative of its importance in the metallurgical arts.

There are two principal oxides of tin, viz., stannous oxide or protoxide of tin (SnO), stannic oxide or binoxide of tin (SnO_2). Stannic sulphide or mosaic gold, and the chlorides of tin are valuable compounds used in decorating, and as a mordant by the dyer and calico printer.

TITANIUM (symbol, Ti, atomic weight, 50),

NIOBIUM, and

TANTALUM

are very rare metals, which need not be described here.



FIG. 55.—A Tin-Mine in Cornwall.

CLASS VII.

MOLYBDENUM, VANADIUM, TUNGSTEN.

The Tungsten Class.

TUNGSTEN.

Symbol, W (Wolfram). Atomic weight, 184.

The only metal of this class that specially deserves attention (the other two being extremely rare) is tungsten. It is a greyish-black powder, which becomes brilliant if burnished, and has a specific gravity of 17.6.

There are two oxides, the dioxide (WO_2) and tungsten trioxide (WO_3).

Tungsten is sometimes employed in the manufacture of steel, to which it is said to impart a peculiar toughness.

CLASS VIII.

ARSENIC, ANTIMONY, BISMUTH.

These metals have already been described (see pages 83—90).

CLASS IX.

LEAD, THALLIUM.

The Lead Class.

LEAD.

Symbol, Pb (Plumbum). Atomic weight, 207.

Lead ore is very abundant in various parts of England: the chief ore is the native plumbic sulphide, protosulphide of lead, or *galena* (PbS). Lead is a bluish-white metal, having a specific gravity of 11.36: it marks paper, and is so soft that it is easily indented with the nail. It is malleable, ductile, and sufficiently tenacious for the purposes to which it is applied. It is easily melted, and fuses at a temperature of 620° F., and is most extensively used for making leaden pipes, cisterns, and for the gutter-work and covering of houses. Type, pewter, Britannia and Queen's metals, all contain lead. The red oxide is used in glass-making, and the carbonate and chromates, with the oxychlorides of lead, are largely employed as pigments.

Lead is the usual messenger of death in modern battles, and receives one of its most destructive forms in the Sneider bullet, which, with its cartridge and self-exploding arrangement attached, is shown at Fig. 56.

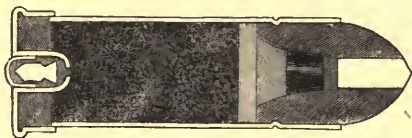


FIG. 56.—*The Sneider Cartridge.*

The terrible slaughter of the army of King Theodorus in the battle that preceded the fall of Magdala was due to the mistake the King made in exciting his troops to attack what he thought were baggage-mules, but which were, in fact, steel guns and rocket batteries. His men, crowded together, were shot down by hundreds. From the Sneider bullets and shells the Abyssinians received the most frightful wounds, and some were discovered after the battle with half their skulls blown off.

There are four oxides of lead: a black suboxide (Pb_2O), plumbic oxide or protoxide of lead (PbO), plumbic dioxide or peroxide of lead (PbO_2), minium or red lead (Pb_3O_4). The sulphide, chloride, oxychloride, and the carbonates of lead represent the most valuable salts of this metal.

THALLIUM.

Symbol, Tl. Atomic weight, 204.

This metal was discovered by Mr. Crookes, the editor of the "Chemical News," who describes his discovery as strictly analogous to that of selenium



FIG. 57.—*The use of the Snelder Rifle in the Battle that preceded the fall of Magdala.*

After a picture by Mr. Baines.

by Berzelius. The observation of a brilliant green line by spectrum analysis in the dust from a pyrites burner led Mr. Crookes to the discovery of this metal, so called from the Greek *θαλλος* (a green tinge), on account of the magnificent green which it communicates to a flame.

Thallium is very soft, in fact it is the softest known heavy metal, being only exceeded in this respect by the alkali metals. A piece of lead scratches it with the utmost facility, without itself receiving an appreciable impression. It also possesses the property of welding together in the cold by pressure.

For all the interesting facts respecting this new metal the reader is referred to Mr. Crookes's lecture "On the Discovery of the Metal Thallium,"* delivered at the Royal Institution, also to the various papers written by the discoverer in the "Chemical News."

* Royal Institution of Great Britain, Friday evening, March 27, 1863. A lecture by William Crookes, "On the Discovery of the Metal Thallium." Pardon, Printer, Paternoster Row.

CLASS X.

COPPER, MERCURY, AND SILVER.

The Silver Class.

SILVER.

Symbol, Ag (Argentum). Atomic weight, 108.

Silver is another of the metals well known and appreciated by the ancients. It is sometimes met with in the native state, but is more generally associated with lead as argentic sulphide. By Pattinson's admirable process the pure lead is crystallized out of the alloy of lead and silver obtained by smelting lead ores containing a certain quantity of silver, and then, by "cupellation," the silver is obtained pure.

Any specimen of lead or galena supposed to contain silver is first powdered, weighed, and then well mixed with twice its weight of sodic carbonate,



FIG. 58.—*Agate Pestle and Mortar.*

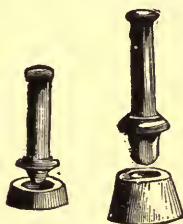


FIG. 59.

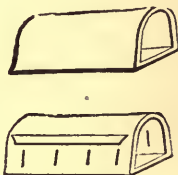


FIG. 60.—*Muffles.*

and 8 per cent. of powdered charcoal. This mixture is placed into a crucible sufficiently large, and gradually heated till the boiling up of the materials ceases, when the heat is urged quickly to a bright redness, and the crucible is then removed and allowed to cool. The button of lead is now placed on a "cupel," made with damp bone-ash compressed into a proper mould (Fig. 59). When the cupel is made it is easily pushed out of the mould and dried. The cupel is now placed in a muffle (Fig. 60), which is made of the same material as the best crucibles. The muffle is, of course, previously heated in a proper furnace, of which most useful examples are given in the cut Fig. 61.

By the proper management of the heat, the lead is oxidized, and sinks into the pores of the cupel, and at last a tiny bead of silver is apparent, which is taken out of the cupel when cold, and weighed.

Silver is a reddish-white metal, and possesses all the best physical properties of a metal, viz., malleability, ductility, and tenacity. It has a specific gravity of 10.53, and melts at 1,873° F. When heated in a small cup or crucible of charcoal in the voltaic arc, it volatilizes, and the hot vapour emits a light, which, passed through prisms, affords two bright green lines (see frontispiece), very characteristic of the presence of this metal.

Pure silver, instead of having, like palladium, potassium, and mercury, the property of absorbing hydrogen, prefers its usual companion, oxygen, and is said to take up, whilst in the liquid state, twenty-two times its bulk of this element. The metal gives out the oxygen when it assumes the solid state.

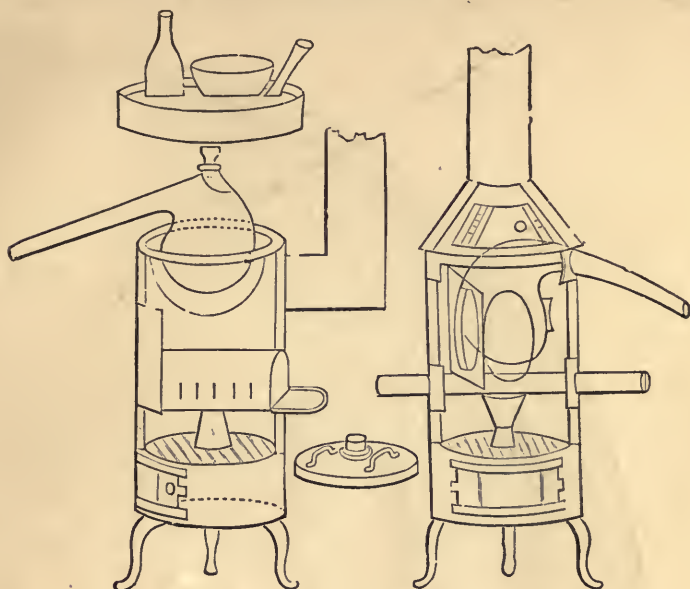


FIG. 61.—Furnaces, for assaying Silver and Gold.

A, furnace arranged with muffles, sand bath above, and retort; B, furnace, with earthen retort, and tube for other experiments. These furnaces are made of sheet iron, lined with fire-clay, and are sold by How, Foster Lane, City.

There are three oxides of silver:

Argentous oxide or suboxide of silver	.	.	Ag_2O
Argentite oxide or protoxide of silver	.	.	Ag_2O
Argentite peroxide	.	.	Ag_2O_2

The argentic sulphide (Ag_2S) is the mineral which yields the largest proportion of silver. The chloride of silver is an important body; there is a sub-chloride (Ag_2Cl), but the symbol of the former, called argentic chloride, is AgCl .

In the assay of silver by the wet process, the determination of the real quantity of the metal in any given specimen is brought within an error of $\frac{1}{5}$ in 1,000, whilst cupellation may vary, even in the most experienced hands, as much as 2 in 1,000. The solution of the alloy is tested by a measured quantity of a standard solution of sodic chloride (common salt); and this test, or that of hydrochloric acid, is so delicate that it will detect one part of silver in 200,000 parts of water. The chloride of silver settles to the bottom of the vessel in which it is precipitated, and it may be



FIG. 62.—Precipitating Glass for Argentic Chloride, with Funnel and Beaker Glass for filtering.





FIG. 63.—Elkington's Milton Shield.

collected, washed, dried, and weighed, to verify the standard solution of salt.

When exposed to the light, it gradually blackens, and hence is used for taking copies of negative photographs, the chloride which is not acted on by the light being subsequently dissolved out by a solution of hyposulphite of sodium. Zinc reduces the argentic chloride to the metallic state.

Argentic chloride is soluble in a solution of potassic cyanide, and is used for silvering. A better silvering solution is the argentic cyanide obtained by precipitating a solution of argentic nitrate with one of potassic cyanide, and dissolving the argentic cyanide in an excess of the potassic cyanide.

From all these solutions of silver the most beautiful works of art are formed by precipitating the silver in moulds by a current of electricity.

FIG. 63 (pp. 120, 121) represents Messrs. Elkington and Co.'s magnificent Milton Shield.

This remarkable work of art in *repoussé* silver has since been purchased by the Government for the South Kensington Museum, and cost the firm nearly £3,000 to make. It received two gold medals at the Great French Exhibition, viz., one for the firm and one for the artist. The great firm of Elkington has now been established in Birmingham and London for many years, and has produced more than any other house those beautiful designs in silver which have raised the character of English silversmith's work to the highest pitch of eminence. Amongst the important works of art made by Messrs. Elkington since the Exhibition of 1862 are the following, all of which have received the highest encomiums from those capable of judging of art-work, to say nothing of the numerous medals awarded:

1867, Paris Exhibition: The Elcho Challenge Shield; the International Challenge Trophy; the Milton Shield (since purchased by the Government for the Kensington Museum); enamelled and silver-gilt baptismal gift from Her Majesty the Queen to the son of H.R.H. the Prince of Wales; bronze statue, 10 ft. 6 in. high, of H.R.H. the late Prince Consort, by W. Theed, Esq., erected at Balmoral; the bronze 8 ft. statues of Oliver Goldsmith and Edmund Burke, both by J. H. Foley, R.A., for the University of Dublin; and they are now proceeding with the four bronze statues, 7 ft. 6 in. high, each intended for the Holborn Viaduct.

There are other useful salts of silver, viz., argentic bromide (AgBr), argentic iodide (AgI), argentic fluoride (AgF), the argentic sulphate (Ag_2SO_4), and especially argentic nitrate (AgNO_3). The argentic phosphates are also worthy of notice.

COPPER.

Symbol, Cu (Cuprum). Atomic weight, 63.5.

Some years ago Professor Tennant, of the Strand, the celebrated mineralogist, deposited a great mass of very hard native copper from North America at the Polytechnic. In England the mines of Cornwall supply the clean copper ore which is smelted at Swansea. The process of roasting, melting and granulating, and gradually refining the metal, is very elaborate.

Copper is extremely malleable and ductile, and has a specific gravity of 8.921 to 8.952; it has a red colour, and emits a peculiar odour when handled. It is used in many different ways for coinage and the sheathing of ships, and is an important constituent of brass and other valuable alloys.

At the Great Exhibitions in this country and Paris, the copper trophies were always conspicuous objects; and the French especially now compete very closely with the English in the manufacture of those large copper vessels called "vacuum pans," used in sugar-boiling, of which the following, taken from Ure's Dictionary, is a good illustration.

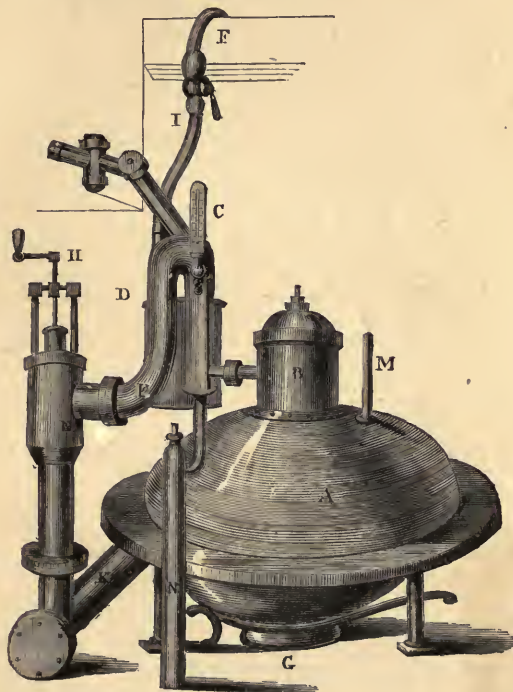


FIG. 64.

A, represents the vacuum spheroid; B, the neck, with the lid. From the side, B, a pipe passes into the lower extremity of the bent pipe, F; D, terminates in the pipe; E, valve connected with the vacuum main pipe, K; F, measure cistern; H, valve for cutting off supply; I, stop-cock; C, barometer; M, proof-stick; N, cistern pipe for excess syrup.

Copper does not oxidize in pure, dry, or moist air, and hence is used extensively in Moscow for covering the domes of churches. There are two oxides of copper, viz., cuprous oxide (Cu_2O), and cupric oxide (CuO). The chief salts of this metal are cupric sulphate ($\text{CuSO}_4, 5\text{H}_2\text{O}$), cupric nitrate ($\text{Cu}_2\text{NO}_3, 6\text{H}_2\text{O}$), cupric sulphide (CuS), cupric carbonate, and hydrated dibasic carbonate or malachite ($\text{CuO}, \text{H}_2\text{O}, \text{CuCO}_3$), so plentiful in the Russian dominions. The art of electrotyping is also carried out by Messrs. Elkington with the greatest success, and the finest works in copper are executed by that house, the metal being deposited from the cupric sulphate by electricity.

MERCURY.

Symbol, Hg (Hydrargyrum). Atomic weight, 200.

The title hydrargyrum conferred on mercury, is derived from the Greek υδωρ (liquid), and αργυρον (silver) or quicksilver. It is sometimes found native, but is usually prepared from cinnabar, a mineral sulphide of mercury.

Mercury is a very brilliant metal, fluid at all ordinary temperatures, and having a specific gravity of 13.56. At all temperatures above 41° F. it volatilizes slightly; hence the danger to workmen using this metal either for silvering looking-glasses, or thermometer and barometer making.

Mercury freezes at — 37° 9' F., and is not tarnished by exposure to damp or dry air at ordinary temperatures.

There are two principal oxides, mercurous oxide or suboxide of mercury (Hg_2O), and mercuric oxide or red oxide of mercury (HgO). The most valuable salts of mercury are the native sulphides, the chlorides of mercury, mercurous chloride or calomel (HgCl), and mercuric chloride or corrosive sublimate (HgCl_2). The mercuric iodide, mercuric sulphate, and mercuric nitrate are some of a long list of mercurial salts presenting many interesting features.

CLASS XI.

GOLD, PLATINUM, PALLADIUM, RHODIUM, RUTHENIUM,
IRIDIUM, OSMIUM.

The Gold Class.

PLATINUM.

Symbol, Pt. Atomic weight, 197.1.

It was the sagacity, the patience, and learning of the late Dr. Wollaston that overcame all the difficulties connected with the manipulation of the ore of platinum, and not only demonstrated how that metal was to be extracted from the mineral, but also invented a method by which the metal, originally in the form of powder, was gradually brought to the solid state, and rendered both malleable and ductile.

The name of the metal is derived from *platina* (little silver), and it was first obtained by Wood in 1741.

Platinum comes chiefly from the Ural Mountains, although some is obtained in Mexico and Brazil, likewise in California and Australia. It is tolerably hard, and has a specific gravity of 21.5. The colour of this metal is white, and when polished it exhibits considerable brilliancy. The ductility and tenacity of platinum have been compared to that of iron.

It is quite infusible by any ordinary furnace heat, but melts in the voltaic arc of a powerful battery; and when enclosed in a hollow made in a lump of pure lime, may be fused, according to the process of Deville and Debray, by the oxyhydrogen blowpipe.

Platinum is largely used for crucibles, tubes, evaporating-vessels required

for laboratory purposes. Platinum foil for batteries and analytical experiments on the small scale, and platinum wire, are indispensable. Large stills, usually gilt inside, are used for the concentration of oil of vitriol: the gilding of the still prevents the acid finding its way through the pores of the metal.

There are two oxides of platinum, the protoxide or platinum oxide (PtO) and platinic oxide, the dioxide (PtO_2); also two sulphides, PtS and PtS_2 .

One of the most important salts of the chlorides is the platinic chloride, always spoken of in the old standard works as the bichloride, but now called the tetrachloride (PtCl_4). By gently heating this salt, finely-divided metallic platinum or platinum black is obtained; or a solution of platinic chloride may be precipitated with ammonium chloride: the ammoniac platinum chloride is collected, washed, dried, and heated red hot, and then forms a finely-divided porous mass called "spongy platinum," which becomes red hot immediately a jet of cold hydrogen gas is directed upon it, because its pores are always full of oxygen, and the two gases, by the intervention of the spongy platinum, unite and form water. This power of condensing gases upon its surface is a very curious property of finely-divided clean platinum. Platinum chloride is always used to determine quantitatively potassium or ammonium in analytical researches.

PALLADIUM and RHODIUM were discovered by Wollaston in the ore of platinum in the year 1803; IRIDIUM and OSMIUM by Tennant in the same year; RUTHENIUM by Claus in 1845. All these metals were discovered in the ore of platinum, and might have been known much earlier if the spectroscope had been in use in the time of Wollaston. The last metal, but certainly not the least in importance, is gold.

GOLD.

Symbol, Au (Aurum). Atomic weight, 196.6.

California and Australia are now only spoken of as modern Ophirs and the lands of gold. Peru, Brazil, Hungary, the Ural Mountains, and even Africa, hide their diminished heads before the first-named countries, although it was from these countries that gold was chiefly obtained up to within the last twenty-five years.

Gold is found in the native state in various forms, sometimes crystallized in octohedral cubes, or tetrahedra occasionally in thin plates, stringy and arborescent, and in irregular lumps called "nuggets;" indeed, the latter title has become a household word, and the expression "he has found a nugget" amounts to an announcement of sudden good fortune.

The colour of gold (a full, rich yellow) is known to all. The specific gravity of this precious metal is 19.34. Gold is too soft to be used alone, and is, therefore, usually alloyed with copper. It takes very high rank in the properties of malleability, ductility, and tenacity. Gold melts at a temperature of $2,016^{\circ}\text{F.}$, and any day, at the Polytechnic, may be seen the conversion of gold wire into a purple smoke by the discharge of the Leyden battery, showing the remarkable division of particles of which this and other metals are capable.

The true solvent of gold is nitro-muriatic acid (*aqua regia*); and after evaporating the solution, the auric chloride is obtained; this, re-dissolved in plenty of water and filtered to get rid of any argentic chloride, is precipitated

with a solution of ferrous sulphate. The gold gradually settles to the bottom of the vessel, and looks like brown mud by reflected, but purple by transmitted, light. The liquid may be poured off, and more water added; the finely-divided gold is then boiled two or three times with hydrochloric acid, and finally, being washed and dried, may be melted in a crucible under borax, or, better still, hydropotassic sulphate.

Gold is used for various ornamental purposes, either spread over other substances, as in the art of gilding, or employed to impart a magnificent ruby red to glass. Perhaps one of the best illustrations of the ingenious use of this metal is in the fabrication of ornaments for the person.

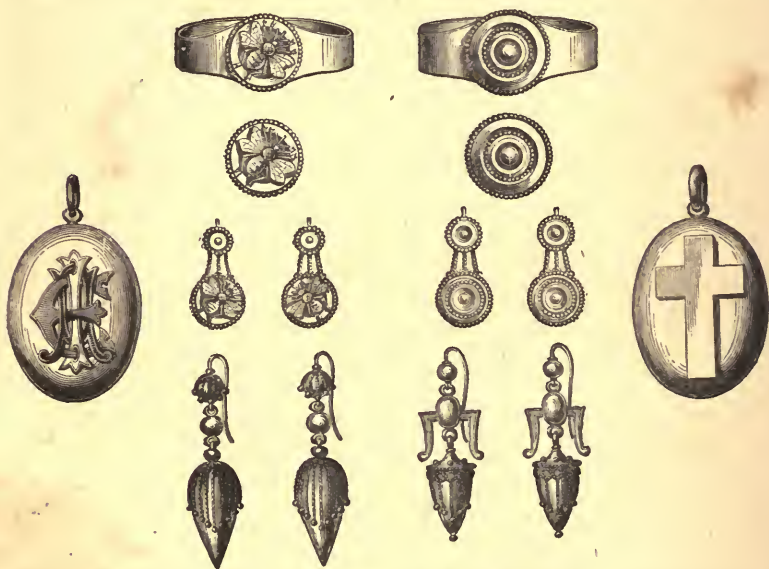


FIG. 65.—Specimens of Streeter's Machine-made Jewellery of 18-carat Gold.

In a little work entitled "Hints to Purchasers of Jewellery," Mr. Streeter has done good service to the public by stating plainly the relative value of the different qualities of gold, and it is from this work the following quotations are taken.

HOW JEWELLERY IS MADE BY MACHINERY.

Mr. Streeter says, "I now proceed to describe the manufacture of golden ornaments; and that this may be the more readily understood, I propose to trace the construction of a bracelet. Suppose a skilled workman be required to fashion one by hand, the process would be this: the necessary quantity of gold having been weighed out—the gold would probably be in a piece of about a quarter of an inch in thickness—it would first be hammered to the required tenuity; then, having cut it into strips, the artificer would construct the flat portion of the bracelet which goes round the wrist, and make the

chenille or raised edge; then he would model the centre ornament by means of the hammer and chisel, and cut out the beads and fasten them on; lastly, he would solder the various parts together, and add the joint and snap.

"The construction would of course in this way occupy much time, and as it could only be accomplished by a skilful workman, the bracelet must necessarily cost a high price.

"But now let us see what machinery can do to lessen both labour and price. In the first place, the gold, instead of being hammered into the required thickness, is passed through the steam rolling machine (*a*, Fig. 66), and can be pressed out to any extent in a few minutes. It is then with the greatest

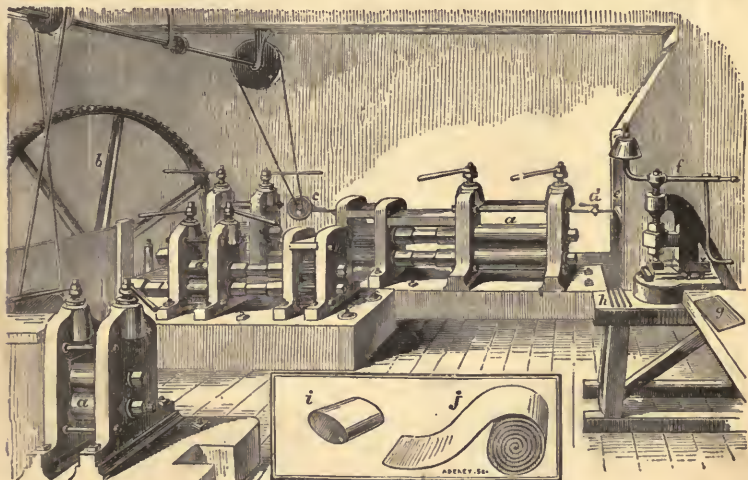


FIG. 66.

a a, rollers; *b*, steam engine; *c*, bellows; *d*, tap to regulate supply of air to furnace; *e*, furnace; *f*, cutting machine; *g*, plate of rolled gold; *h*, thin slips of gold cut from plate; *i*, cake of gold; *j*, the same rolled.

rapidity cut into strips by the cutting press (*f*, Fig. 66). A die (Fig. 67) having been prepared (and every one who has a monogram for his note-paper knows how quickly and inexpensively dies are made), a strip of the gold is put into the "monkey press," an apparatus of considerable power, and with two separate blows the two halves of the bracelet are stamped out. Meanwhile, by means of another die and *press of less power*, the centre ornament is with equal facility formed; and all that remains for the workman to do by hand is to joint the bracelet and put on the snap, and to polish it.

"In the ornamentation of jewellery gold wire of different degrees of fineness is used. This wire is made as follows: the gold is first cut into strips by means of the cutting press. Each strip is then forcibly drawn through an aperture in a steel plate, which rounds it and forms it into wire. This is again passed through apertures, smaller and smaller, until the required size is obtained. These plates are called "gauges," and are capable of attenuating wire to any extent. It requires considerable power to force the strips through the

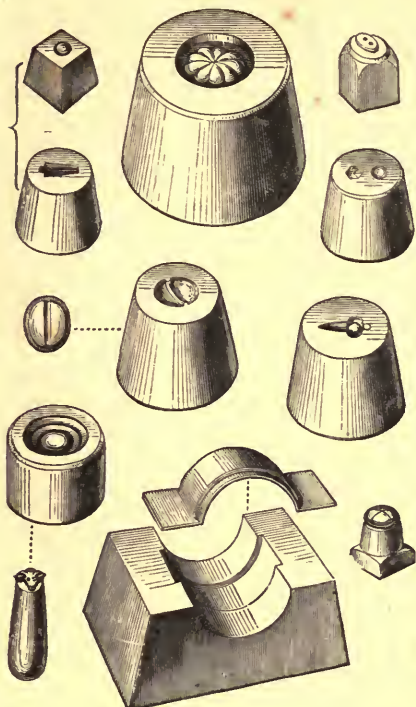


FIG. 67.

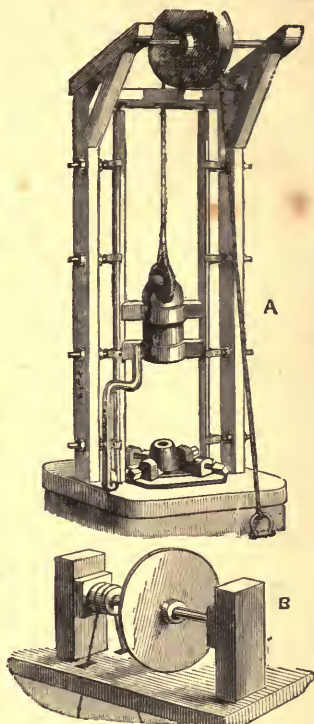


FIG. 69.—The Lapping Machine, used for polishing the bright parts of Gold Ornaments.

FIG. 68.—The Monkey Press.

gauges, and this power is obtained by means of the "drawbench." This description refers, of course, to plain wire only; ornamental wires have to undergo an additional process.

"A bracelet would take a skilled workman *six* days to make by hand, whilst, with the aid of the machinery I have described, the same ornament, including the necessary hand-work, such as jointing, polishing, &c., can be made in *two* days.

"From the above brief description it will be readily understood how it is that really good jewellery may be obtained at a comparatively small cost, and yet a good profit may be had by the vendor. The price of the gold contained in any one ornament is the same, both to the jeweller and to the purchaser; the profit to the former is—or ought to be—derived from the workmanship, and the more quickly he can manufacture such articles, the cheaper he can sell them, getting for himself a fair profit, and giving to the public advantages which they could not have had under the old system.

"Pure gold is represented by the figures 24, and is called 24-carat gold; but

it is seldom to be procured in a state of perfect purity, as it requires a long chemical process so to obtain it, which adds so much to its cost that it is too expensive for commercial purposes. That which is called 24-carat is really only $23\frac{1}{2}$ or $\frac{7}{8}$, which is quite good enough for all practical purposes. This being purchased by the manufacturing jeweller, is alloyed according to his taste or conscience; which latter, I am afraid, is not always of the most sensitive nature."

TABLE SHOWING THE DIFFERENT QUALITIES OF GOLD MANUFACTURED IN DIFFERENT PARTS OF THE WORLD.

		Carat.	£	s.	d.		Carat.	£	s.	d.		
England	From	1	0	3	6	to 22	worth	3	17	10½		
France	"	18	"	3	3	8½	Only common by spe-					
Denmark	"	18	"	3	3	8½	cial permission.					
Baden	"	14	"	2	9	6½						
Germany (all States)	"	12	"	2	2	5½	to 15	worth	2	13	1	
Russia	"	15	"	2	13	1	"	22	"	3	17	10½
Austria	"	10	"	1	15	4½	"	18	"	3	3	8½
Italy	"	12	"	2	2	5½	"	22	"	3	17	10½
Holland	"	4	"	0	14	2	"	22	"	3	17	10½
Africa	"	23	"	4	1	6						
India	"	22	"	3	17	10½	"	23½	"	4	3	1½
Rome	All	18	"	3	3	8½						
United States	From	1	"	0	3	6	"	18	"	3	3	8½
Norway and Sweden	All	18	"	3	3	8½						
Belgium	From	18	"	3	3	8½	"	22	"	3	17	10½
Spain	All	18	"	3	3	8½						
Switzerland	"	18	"	3	3	8½						
Geneva	From	14	"	2	9	6½	Watch-cases only.					
China	"	16	"	2	16	7½	to 23¾	worth	4	4	0	
Japan	"	18	"	3	3	8½	"	23¾	"	4	4	0
Brazil	All	18	"	3	3	8½						
Hamburg	From	13½	"	2	11	3½	"	18	"	3	3	8½
Turkey	"	18	"	3	3	8½						
Greece	"	10	"	1	15	4¼	"	16	"	2	16	7½
Persia	"	3	"	0	10	7½	"	23½	"	4	3	1½
Egypt	"	18	"	3	3	8½						
Rio Janeiro	Imported from	1	"	0	3	6	"	22	"	3	17	10½
Chili	"	1	"	0	3	6	"	22	"	3	17	10½
Peru	"	1	"	0	3	6	"	22	"	3	17	10½
Siam	Nearly pure, fine work.											
Australia	Same as England, except that made up from the diggings.											
Mexico	Principal manufacture fine.											

Any quality is allowed to be imported into these countries.

"The kinds of gold best adapted for manufacturing purposes are 18 or 16-carat. Trinkets made of these qualities not only keep their shape and hardness, and allow of designs of delicate and intricate workmanship, but are of fair proportionate value to the purchasers. What is called standard or guinea gold is made of twenty-two parts pure gold and two of alloy. Of this quality gold coins are made.

ORGANIC CHEMISTRY.

FROM the air, water, and various natural substances contained in the earth, we derive all the bodies that have been discussed in the list of non-metallic and metallic elements. These elements have been spoken of as if they belonged only to dead matter: it is, however, clear that some of these elements are operated upon, and are only built up into complex organic compounds, by the influence of vitality. Thus it is we have organized matter, such as woody fibre, cellulin, bone, muscle, and nerve matter. All these things have been connected with life: the chemist could not take the elements of which they are composed and put them together again, to re-form muscle or nerve matter. Analysis, but not synthesis, is the ruling power in organic chemistry. There are, however, organic compounds that will crystallize, and which possess a constant and exact composition, and yet it cannot be said they are organized.

The alkaloids of the cinchonas, or those contained in opium, oxalic acid, sugar, the alkaloids of coffee, tea, chocolate, are all examples of organic compounds, although they do not betray any organic structure such as would be seen with the aid of a microscope in the various tissues or parts of a living animal or plant.

The field of inquiry included under the head of organic chemistry is, therefore, of vast extent: it not only treats of the nutrition of animals and vegetables, but discusses elaborately the solids and fluids and bases of animal origin. It analyses and discovers the nature and properties of resins, gums, colouring matter, essential oils, essences, the alkaloids, the fatty and vegetable acids, and organic acids in general; products obtained from sugar, alcohol, glycerine; the ethers; and all the interesting changes brought about by fermentation. In the limited space at our command the analysis of organic bodies only can be briefly alluded to. In the analysis of an inorganic salt, such as cupric sulphate, it is always usual to speak of the proximate and ultimate constituents: the proximate constituents would be oxide of copper, sulphuric acid, and water; the ultimate elements, copper, oxygen, sulphur, and hydrogen. So it is with organic compounds: the coffee-berry consists (according to Payen) of the following proximate constituents:

Ligneous tissue	Compound of caffeine with potash and
Hygroscopic water	chlorogenic (caffeic) acid
Fixed fatty matter	Aromatic essential oil
Gum, sugar, and a vegetable acid	Solid fatty essence
Azotized matter analogous to legumine	Saline matters.
Free caffeine	

The whole reduced to ultimate elements would be represented by carbon, oxygen, hydrogen, nitrogen, potassium, and phosphorus.

The analysis of an organic body is, therefore, commenced by a careful separation of each proximate constituent, and these are subjected to a separate investigation with respect to their individual properties, and finally to an ultimate analysis. The organic substance must be carefully dried, and, of course, should be free from all impurity or admixture with any other organic body; and as the ultimate composition can only be obtained by its so-called "destruction," or rather combustion, the material (say sugar) is placed in a glass tube of hard Bohemian glass, 15 in. long and $\frac{1}{2}$ in. in diameter, as marked D, E, F, in Fig. 70, and this is laid in a sheet-iron trough or furnace, A B, in which red-hot charcoal is carefully placed. If sugar alone were put in the tube, destructive distillation only would take place, and the ultimate analysis could not be carried out to the end; it is usual, therefore, to mix with the organic substance some material that will afford oxygen. The body usually employed for this

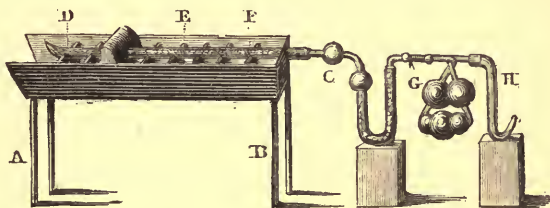


FIG. 70.—*Apparatus for Organic Analysis.*

purpose is oxide of copper, and numerous precautions are taken not only in weighing out the dried substance under examination, but in mixing it with the oxide of copper, and finally placing it into the combustion-tube.

Sugar consists of carbon, oxygen, and hydrogen, and is resolved into water and carbonic acid when heated with oxide of copper. To separate the water, the glass bulb C, with a tube containing chloride of calcium, is attached to the combustion-tube, and receives and retains the water, whilst the carbonic acid is absorbed by a solution of potash of a specific gravity of from 1.25 to 1.27 in the bulb-tube, G; beyond the potash solution bulb is another tube, H, containing fragments of hydrate of potash, which arrests any moisture and carbonic acid that may pass the dessicating tube and potash bulbs. The careful and patient weighings of the combustion tube against the condensing tube and potash bulb supply data which the chemist works into the formula representing the substance under examination.

The student who desires to become a proficient in the analysis of organic bodies should consult Dr. Miller's "Elements of Chemistry," or Liebig's "Handbook of Organic Analysis," and after working upon sugar until his figures are constant, he may then go on to the analysis of organic bodies containing nitrogen. Here again another series of precautions must be taken, which are fully described in the works already alluded to.

In the various kinds of organic analysis the ingenuity of the chemist is taxed to originate tubes of different shapes to answer special purposes. (See Fig. 71.)

When it is necessary to restore the whole tube system used in organic

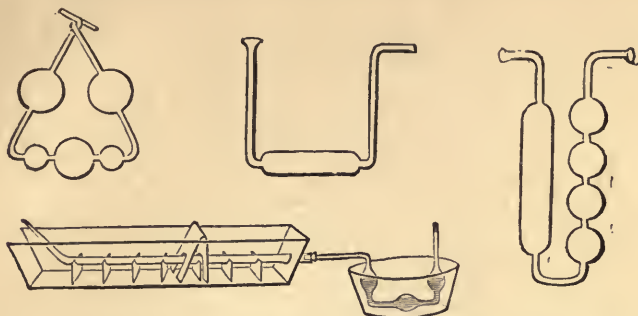


FIG. 71.—*Tubes and Bulbs that may be employed in Organic Analysis.*

analysis to the normal condition, so that each tube and bulb is filled with atmospheric air, an aspirator is attached. The vessel C, Fig. 72, is called the aspirator, because it sucks or draws the atmospheric air into the tubes.

The combination of organic bodies may also be effected with pure oxygen gas, assisted by Hoffman's furnace, in which the heat is produced by burning gas. Forty years ago, the teacher (Mr. John Thomas Cooper) under whom the writer studied, invented a very excellent apparatus for organic analysis, in which the heat was produced by the combustion of alcohol.

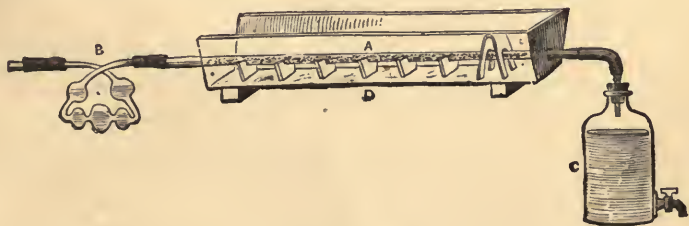


FIG. 72.

A, the combustion-tube; D, furnace; B, potash bulb; C, bottle full of water: whilst the latter runs out, air must pass through the various tubes, and as they were weighed in the first place when they contained air, so the last weighing would be incorrect unless the various tubes contained the same gaseous medium.

The facts supplied by the careful and plodding experiments of numerous chemists in organic chemistry have supplied Laurent, Liebig, Gerhardt, and their followers with the facts which have created a new nomenclature in organic chemistry, extending to the whole range of chemical science, inorganic as well as organic.

Contributions to, and knowledge of, organic decomposition are always valuable; and as a sequel to this brief article may be noticed the curious experiments lately made by Dr. B. Richardson, F.R.S., which are fully detailed in the "Medical Times and Gazette," 9th January, 1869, as follows:

EXPOSURE OF ANIMAL SUBSTANCES TO WATER GAS AT A HIGH TEMPERATURE—340° F.

The learned author says :

"I woke one day not long since from sleep with a dream before me in wonderful reality. I thought I had been at work in the laboratory subjecting animal structures to the same process as that to which the dentist subjects vulcanized india-rubber when he is making vulcanite base. The dream, childish as it was, as coming from no traceable line of connected thought, seemed to me to be worth accepting as a hint to positive work, and so I followed up the ideal by the real, with results which I propose to describe to-day as simply as I have read them.

"We take for our purpose the common vulcanizing apparatus used by the dentist, and depicted in the diagram (Fig 73). It is a very strong chamber

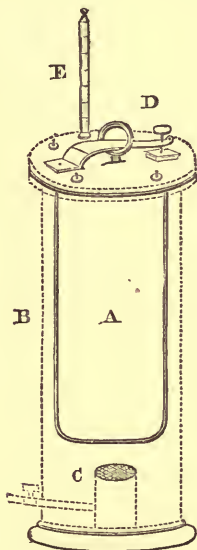


FIG. 73.

A, iron cylinder; B, stove; C, gas burner; D, lid with safety-valve; E, thermometer.

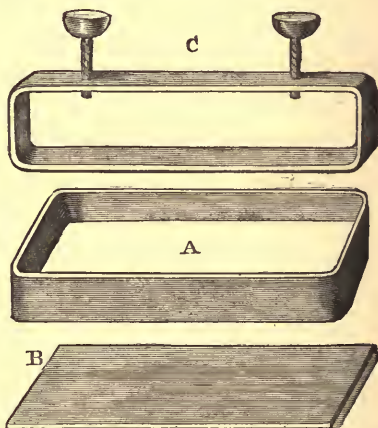


FIG. 74.

A, flask ready for filling; B, loose lid; C, encircling band, with compressing-screws.

of iron, enclosed in an iron case or stove, with a series of gas burners at the lower part of the stove. The iron chamber, which receives the substances to be operated upon, is heated by the burners. It is furnished with a heavy iron lid with binding-screws, a safety-valve, and a tube for holding mercury, in which a thermometer is inserted. When we are about to use the apparatus, we place our specimens in the chamber with a little water. The apparatus I have used, and which has been kindly lent me by my good friend and

neighbour, Mr. Ballard, has a chamber 10 inches deep and 5 inches in diameter. Six or eight fluid ounces of water in the chamber answer very well for one series of experiments; but the quantity may be varied, by which different results may be obtained. Having, then, placed our specimens and the water in the iron chamber, we screw on the lid firmly, interposing what may be called a washer of brown paper between the lid and the chamber at the part where they touch; we screw down the safety-valve, interposing between it and the small opening it covers also a layer of brown paper; we put the thermometer into the mercury, light the gas, and watch the rise in the thermometer up to the point of heat required. The necessary degree of heat obtained, the gas is turned a little down and moderated until the mercury remains steadily at one point, and the experiment is continued for whatever length of time may be desired.

"The specimens of animal structures to be experimented on may be introduced into the chamber in different ways. In some cases we place the specimen directly in the chamber in or above the water; in other cases we put it in an iron flask filled with wet plaster of Paris, lime, carbonate of lime, powdered carbon, clay, powdered Portland stone, or other substance, and subject the whole to pressure by compressing-screws. I have constructed a very convenient iron flask for this purpose. It consists of a framework of iron, with two plates of iron to make a false top and bottom. The frame laid on the lower plate forms a flask, and into it the plaster of Paris, or clay, or sand, or carbon, moistened with water, is placed, with the specimen embedded. Then the upper plate of iron is dropped on, an encircling band of iron is passed over the whole lengthways, two screws in this band are brought forcibly down on the upper plate of the box, and thus the specimen, with the substance in which it is buried, is firmly encased. The iron flask, in this way arranged, is now ready to be placed in the chamber. The advantage of this flask is, that when the exposure to heat is completed and the metal is cooled down, on setting free the iron band the false top and bottom can be removed, and the specimen can be cut out with a small keyhole-saw from its iron framework. The flask is depicted in the diagram (Fig. 74) in parts.

"Having stated these preliminaries, I pass to describe some of the results which up to this time have been obtained.

"BLOOD.

"Into the chamber of the apparatus a portion of blood-clot, from the blood of an ox, was placed on a shelf with 8 oz. of water beneath. The lid of the chamber was firmly adjusted, the heat was raised to 340° F., and was sustained at that degree for one hour and a half. The heat was then withdrawn, and some hours were allowed for cooling. On opening the iron chamber, the blood was found almost unaltered in shape, but altogether changed in consistence and structure. It felt like simple caoutchouc, but broke with a bright surface like Spanish liquorice. The natural characteristics of the blood were lost, and on gentle drying the mass became brittle, closely resembling jet. A specimen of blood thus treated has been examined by my friend Dr. Sedgwick, who reports upon it, that it 'was a bright black, friable, jet-like material. Gently rubbed down with a little distilled water, it formed a reddish-brown fluid, which under the microscope was seen to consist of a coloured liquid, and reddish granular masses of various sizes. Very many were about one-sixth the size of a blood corpuscle, reddish-brown, and very irregular in shape. As the

solution dried, one or two irregularly hexagonal crystals made their appearance. The substance, after twenty-four hours' soaking, was partially soluble in strong solution of ammonia, very slightly in distilled water, and hardly at all in dilute hydrochloric acid and in methylic alcohol; it was untouched in ethylic ether and in chloroform.

"Into the iron box or flask plaster of Paris was poured in the fluid state, and a clot of fresh blood was immersed in the plaster. The lid was placed on the box, and when the plaster had set firmly, the whole was placed in the chamber with 6 oz. of water. The temperature was raised to 340° , and sustained for an hour and a half. On breaking up the plaster, after cooling, the blood was found in the same state as that named in the experiment described above.

"ALBUMEN.

"An egg was placed in the iron flask and surrounded with plaster of Paris in the fluid condition. When the plaster was entirely set, the flask was put into the chamber with 6 oz. of water, the temperature was raised to 340° , and was sustained for an hour and a half. After cooling, which was very rapidly effected by immersing the flask in cold water, I found, on removing the egg, that the shell was nearly full of a beautiful transparent golden or amber-coloured fluid, very thin, and running like dissolved gelatine. In the course of a few hours this fluid was slightly gelatinized. The membrane lining the shell was detached, but not destroyed; the shell was dry, brittle, and firmly attached to the surrounding plaster. The experiment was repeated with another egg, but was modified by allowing the apparatus to cool very slowly in the air at 60° . On breaking the plaster, and cutting through the egg, no fluid was found, but in the centre a soft yellow substance (probably the yolk), about the size of a hazel nut, and slightly glistening on the surface. On gently drying this substance, it became firm, retaining its colour, and looking like amber, but not so hard.

"THE BODY OF A TOAD IN CARBON.

"The iron flask was partly filled with fluid plaster of Paris. On this layer a bed of vegetable carbon, in fine powder, was laid, and the body of a toad recently dead was buried in it. The carbon mound was next enclosed in plaster; the flask was closed, and half an hour later it was placed in the iron chamber with 10 oz. of water. The temperature was first raised to 350° F., but was brought down to 340° , and was retained at this degree for an hour and forty minutes. The gas was then turned off, and the apparatus was allowed to cool slowly. On opening the flask, the body of the animal was found to be altogether destroyed, and so mixed with the carbon that no part of it could be defined.

"THE BODY OF A FROG IN SAND.

"The body of a frog recently dead was buried within the iron flask, in moist fine sand compressed with moderate firmness. The flask was then put into the iron chamber, with 6 oz. of water, and the temperature was raised to 340° F., and sustained for an hour and a half. The flask was opened twelve hours afterwards, and the results of the experiment were found to be nearly the same as when carbon was employed. The animal was destroyed, and no distinct organ or structure could be distinguished.

"BODY OF A FROG IN PLASTER OF PARIS.

"Fluid plaster of Paris was poured into the iron flask until the flask was half full. The body of a frog recently dead was now laid on the plaster, and allowed to mould itself to it. When the plaster had become rather firm, another quantity of fluid plaster was poured in, so as to bury the frog completely and fill the flask. An hour later, the flask, which had been closed with pressure, was placed in the iron chamber. The temperature was raised to 340° F., and sustained for two hours. Twelve hours later the flask was opened, and a mould of the frog was found, the organic soft parts of the body having been destroyed. At the lower part, in the centre, was a black spot: the spot consisted of blood which had gravitated to the lowest part. Besides this, there was a little *débris* of earthy part of bone within the mould. The impression of the body was beautifully marked in the plaster.

"BODY OF A FISH IN PLASTER AND ALUM.

"Some plaster of Paris, made into a fluid with water containing alum in solution, was poured into an iron flask until the flask was half filled. The body of a dead fish, a common sprat, was cut in halves transversely, the two

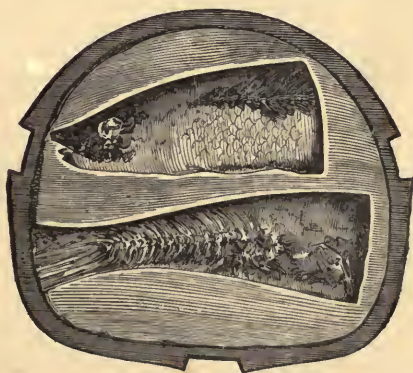


FIG. 75.—*Body of a Fish in Plaster and Alum.*

halves were laid upon the plaster, and the flask was filled up with fluid plaster and closed. When the plaster was firm, the flask was placed in the iron chamber, with 4 oz. of water, and the temperature was raised to 340° F., and was sustained at that degree for an hour. Twelve hours afterwards the flask was laid open, and the plaster cut in halves, when two moulds were found, one of the upper, the other of the lower half of the fish. The markings of the body of the fish were delineated on the mould; a small portion of bone (spinal) was left; a dark-coloured fine spot, surrounded by a shiny scaly substance, indicated the position of the eyeball; a little filamentous *débris* remained, consisting probably of the scaly covering of the animal."

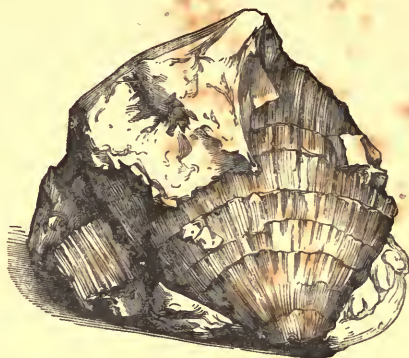


FIG. 76.—Oyster-shell subjected to same process.

After perusing the account of Dr. Richardson's experiments, the mind reverts to the formation of natural fossils, and the remarkable imitation of nature with pressure and heat, which produces these *quasi*-fossil moulds in plaster of Paris. Fossils have been spoken of as "the medals of creation;" who would dare (unless they were makers of artificial flint-head arrows) to imitate so closely? But the forgery in this case is an advance in science, and no doubt will assist the geologist and palæontologist to make speculations (this time) founded on actual experiment. In bringing this work to a conclusion, the writer desires it to be understood that he has endeavoured to fulfil a promise made in his first elementary work on science, and that was, to try to lead the youthful and unlearned reader further on in the pursuit of that science; the beginning of which, Sir Humphrey Davy said, is pleasure; its progress knowledge; its objects truth and utility.

It is said that Demosthenes first conceived his passion for eloquence upon hearing the orator Callistratus, and witnessing the applauses with which his performance was rewarded; that Tycho Brahé resolved to devote his life to astronomy in consequence of his witnessing, when a child, an eclipse of the sun. Surely amongst the thousands of young people who attend scientific lectures, there must be undeveloped geniuses who might, if they read and practise scientific experiments, become as useful and as celebrated as a DAVY, a FARADAY, or a WHEATSTONE!





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